WORLD METEOROLOGICAL ORGANIZATION

COMMISSION FOR AGRICULTURAL METEOROLOGY

CAgM Report No. 102

USE OF SEASONAL FORECASTS AND CLIMATE PREDICTION IN OPERATIONAL AGRICULTURE

Prepared by

M. Harrison, A. Kanga., G.O. Magrin, G. Hugo,
I. Tarakidzwa, C. Mullen, H. Meinke

Report of the Working Group on the Use of Seasonal Forecasts and
Climate Prediction in Operational Agriculture

WMO/TD No. 1344

Geneva, Switzerland

March 2007

TABLE OF CONTENTS

ABSTRACT

The Commission for Agricultural Meteorology (CAgM) at its 12th Session held in Accra, Ghana, 18-26 February 1999, established the Working Group on the Use of Seasonal Forecasts Climate Prediction in Operational Agriculture.

The Terms of Reference of the Working Group are:

a) In liaison with the CLIPS project, review and summarise the current advances in seasonal forecasts and climate prediction and the products and services relevant to agriculture that are becoming available based on the forecasts

b) To survey and summarise, using appropriate case studies, the current applications and possible impacts of seasonal forecasts and climate prediction in agriculture, forestry and livestock management

c) To review and recommend ways to use and disseminate optimally the seasonal forecasts and climate prediction in operational agriculture with emphasis on user needs especially in the tropical and subtropical zones

d) To assess the potential of predictions in Early Warnings to reduce the adverse impacts of climate events on agriculture, forestry and livestock management.

The Commission for Agricultural Meteorology Working Group on the Use of Seasonal Forecasts and Climate Prediction in Operational Agriculture met in Geneva, 15-18 January 2002. Members of the Working Group who were present included: Ms Claire Mullen of the Australian Bureau of Meteorology; Mr Gualterio Hugo of the National Meteorological Service of Chile; Mr Alphonse Kanga of the Meteorological Service of Niger; and Mr Isaac Tarakidzwa of the Zimbabwean Meteorological Service. Dr Mike Harrison of the Met Office, United Kingdom, chaired the Group and the Commission was represented by Dr Sivakumar of the WMO Secretariat. In addition to the above participants, a report was added to this document by a team of scientists working on climate forecasts in the cropping system of South Asia. These authors include: Dr H. Meinke from the Department of Primary Industries of Queendland, Australia, Dr J. Hansen from the International Research Institute from the USA, Dr Selvaraju from the Agricultural University in India, Dr S. Gadgil from the Indian Institute of Science in India, Dr K. Kumar from IITM, India and Dr M. Aslam from the Pakistan Agricultural Research Council in Pakistan.

The meeting of the Working Group was well-timed from two perspectives. First, the Commission for Climatology had met in November 2001 and had agreed the formation of a number of Open Programme Area Groups (OPAGs), the activities of which had substantial relevance to the activities of the Working Group. With the Commission for Agricultural Meteorology planning to discuss the formation of its own OPAGs at the meeting in Ljubljana in October 2002, the Working Group was in the position of being able to consider recommendations pertinent to these new management structures.

Secondly, a period of four years had elapsed since the El Niño event of 1997/98, a period which has seen substantial growth in activity relating to seasonal prediction and the delivery to and the use of these predictions in many applications areas, most prominently agriculture. The impact of climate variability on social structures has been well known, but the magnitude of that impact and the potential of predictions to help mitigate or exploit those impacts have rarely received such clear focus as in 1997 and 1998. Thus the Working Group had the opportunity to review the situation with the hindsight benefit of distance from the El Niño event.

It is clear in the Members' reports that the level of activity is substantial in many parts of the world. The levels of skill available in the predictions has been enhanced by the implementation of the array of moored buoys in the tropical Pacific Ocean, with further gains possible as the ocean observing systems become increasingly comprehensive. The models themselves have developed substantially in recent years, alongside an increase in computing power that now permits some centres to produce operational ensembles using coupled models. Many meteorological services around the world have their own in-house prediction capabilities, mainly through use of empirical models but with a growing number examining the use of Regional Climate Models run on workstations and advanced personal computers.

Forecasts are now freely transmitted around the globe by the Internet, often in a form directly available to users, in a manner that can be utilised by the NMHSs. However in several parts of the world interpretation and delivery of the climate prediction information has been promoted more through the development of Regional Climate Outlook Forums, in which both meteorological services and agricultural end users participate, than through information availability on the Internet. Further dissemination initiatives are assisting with the problem of information delivery to remote regions, and here the RANET project, with its use of wind-up radios and digital satellite transmissions, stands out. There are now few technological barriers to the access to and the onward transmission of forecast information, although the probability format in which forecasts are normally presented continues to create interpretative difficulties.

Climate information, often without predictions *per se*, is being provided in increasingly sophisticated ways in several parts of the world, in particular in Australia. Agriculture is frequently the target of this approach, and some encouraging results have been obtained indicating that farmers are capable of making decisions leading to improved yields when provided with this information and trained in its use. Although there are a number of cases in which the benefits of seasonal predictions themselves can be demonstrated, there still appears to be limited evidence that a consistent return to agriculture is achievable from these predictions. There is a clear need for a continuation of activities correctly designed to examine approaches to the extraction of value from the predictions and to estimating the overall value thus obtained.

Having reviewed the current status of seasonal forecasting, its production and its delivery, within the context of agricultural applications, the Working Group was able to make a number of recommendations related to each of its ToRs. These recommendations might be considered by the Commission for Agricultural Meteorology in the proposed introduction of OPAGs and might also link in with the activities of the OPAGs of the Commission for Climatology. Within the first Term of Reference the recommendations relate to improving the manners in which forecast information is presented and verified in order that it might become more accessible to and interpretable by agricultural users. For the second Term of Reference the recommendations refer to improving the current level of knowledge of achievements in agricultural applications and to ensuring wide dissemination of information about successful approaches. Under the third Term the Working Group made recommendations on developments in dissemination procedures and in the training of meteorologists and agricultural end users. Finally the Working Group recognised under the fourth Term of Reference that inadequate use is made of predictions in Early Warning systems and made appropriate recommendations on initial steps to be taken towards improving that situation.

CHAPTER I

REPORT TO THE COMMISSION FOR AGRICULTURAL METEOROLOGY WORKING GROUP ON THE USE OF SEASONAL FORECASTS AND CLIMATE PREDICTION IN OPERATIONAL AGRICULTURE

M. Harrison
Hadley Centre, Met Office,
London Road, Bracknell, Berks RG12 2SY
United Kingdom

1.1 Introduction

There have been significant advances in the four years during and subsequent to the El Niño event of 1997/98 in seasonal prediction, in its methods, its delivery, and in its applications in many sectors. Perhaps most effort has been placed in agriculture as far as applications are concerned, and projects have been developed in many parts of the world. Some of the key developments are summarised in this report, although the projects listed are limited in comparison to those that have been, or are being, run. This report is divided into sections defined by the four Terms of Reference (ToRs) of the Working Group (WG).

1.2 Terms of Reference (a) – In liaison with the Climate Information and Prediction Services (CLIPS) project, to review and summarise the current advances in seasonal forecasts and climate prediction and the products and services relevant to agriculture that are becoming available based on these forecasts

In a survey undertaken during the year 2000 on behalf of the Climate Information and Prediction Service (CLIPS) Project (Kimura 2001) it was revealed that about one-third of the World Meteorological Organisation (WMO) Membership already had, or planned to obtain in the near future, the capability to provide some form of operational seasonal to interannual prediction (SIP). It is also known that a substantial number of Members that did not reply to the questionnaire also have, or plan, these capabilities, and therefore the true proportion of the Membership with capability is certainly higher than one third. Additionally a number of other organisations, such as universities and various research centres, as well as commercial concerns, also possess prediction facilities. The number of individual models/techniques for producing seasonal to interannual predictions is unknown, but the results of the survey indicate the level of interest that exists and the interest in retaining in-house capabilities when global numerical predictions are readily available through the Internet.

According to Kimura (2001), by far the majority of the models in use predict only for single countries, rainfall is the most popular predictand, usually the forecasts are for a single three-month season (or a part of this period) at zero lead, and in the vast majority of cases empirical models are used. Of course some centres are able to produce forecasts on scales up to the globe using numerical models, other specific predictands (including direct agricultural variables such as maize yield) are used, some forecasts go out to a year or perhaps a little beyond, and at a few centres the most advanced coupled ocean-atmosphere models are employed. These developments, which have quickened in pace since the 1997/98 El Niño event, have been built on the improved knowledge of links between slowly-varying anomalies of sea surface temperatures and rainfall on seasonal time scales, links which facilitate the creation of empirical models. In Africa alone, following an initiative from the African Centre for Meteorological Applications for Development (ACMAD), most sub-Saharan Meteorological Services possess an in-house single season empirical rainfall prediction model.

Advances are being made in dynamical prediction, with a variety of models of different complexities being focussed on the task. Coupled systems, the most complex, include full global models of both the atmosphere and the oceans. Simpler systems may use a relatively straightforward method (perhaps empirical) of predicting sea surface temperatures and then run a full atmospheric model using these forecasts. Other models focus only on predicting sea surface temperatures, most generally in the tropical Pacific Ocean, and may then be used in a relatively simple empirical manner to predict impacts. Other combinations are possible. A recent trend is to examine the potential use of Regional Climate Models (RCM). These are complex atmospheric models that only handle a relatively small region (perhaps the size of Europe) but with far more resolution than is possible using present global models, and that use boundary conditions supplied by a pre-run of a global model. It is hoped that outputs from such models may provide greater temporal and spatial detail than is available from the global models. Relatively cheap workstations, and even Pentium 4-equipped PCs, are all that is required to run an RCM, and a number of experimental systems are running in various countries with and without other numerical capabilities using boundary conditions supplied by a global centre.

One of the most important developments in recent years has been perhaps the rise of the multi-model ensemble. Current understanding of the workings of the chaotic nature of the climate system indicates that consistently successful deterministic predictions are not achievable. This theory indicates that, from a scientifically-consistent perspective, the only valid form for predictions is probabilistic. Most empirical models provide only deterministic forecasts, although often these are converted into probabilistic form through consideration of the past performance history of the model. Numerical models, on the other hand, provide the opportunity to examine the sensitivity of a given prediction to changes in a number of key inputs to that prediction. In the earliest research the initial conditions that the model started from were adjusted through a series of consistent sets, although in general the sea surface temperatures were kept similar in each run (or ensemble member). It can be surprising how dissimilar predictions can become when started from slightly different initial conditions, not always but often. These early studies confirmed the value of the ensemble approach. There are other uncertainties in the system in addition to the initial conditions, one being the manner in which each particular model ‘describes’ the atmosphere and/or ocean, and often models known to possess skill can give substantially different outcomes in similar situations. It is now known that use of multiple models, each running their own ensemble from varying initial conditions, provides an improvement in skill not available from a single model alone. In Europe, under the DEMETER (Development of a European Multimodel Ensemble system for seasonal to interannual prediction) project, plans are being drawn for an operational system using multiple coupled models. Multiple model systems have been examined in Europe under the PROVOST and DEMETER projects, in the USA under the DSP (Dynamic Seasonal Prediction) projects, internationally under SMIP (Seasonal forecast Model Intercomparison Project), and a new multi-organisation centre based in Seoul, South Korea, the Asia-Pacific Climate Network (APCN), is being established which will also use multiple model inputs.

Skill levels in SIP remains a complex issue. Undoubtedly there is prediction skill at the scientific level, but it is more difficult to interpret the skill at the application level. Nevertheless evidence is accumulating that applications can benefit, although perhaps not universally, from the forecasts at their current levels of skill. From the scientific perspective a number of rudimentary, generalised statements may be made regarding skill. For example, skill is inclined to be higher in tropical regions rather than at higher latitudes. Skill also tends to be higher in the tropics at longitudes closer to the Pacific basin. Nevertheless those extra tropical areas influenced directly by the ENSO (El Niño/Southern Oscillation), such as parts of North and South America and Australia, enjoy more skilful forecasts than those elsewhere, such as Europe. According to one of the results from PROVOST, European skill may be higher in general when there is an El Niño or a La Niña in progress. Levels of skill may change through the year – in particular ENSO-based predictions that forecast through the March-May period have less skill than those for other times of the year (the so-called ‘predictability barrier’). Forecast skill in mid-latitudes are often higher in winter and spring than in summer and autumn. Fields that are spatially more homogeneous on the large scale, such as temperature, have higher skill than those that contain important detail on smaller scales, such as rainfall. Skill tends to decline as forecast lead increases; indeed there are relatively few statistics on skill levels of concern to applications other than at zero and perhaps one-month lead. Much of the current skill emanates from knowledge of sea surface temperature anomalies in the tropical Pacific Ocean, but additional skill is available from the other tropical basins and perhaps anomalies at higher latitudes. The most advanced prediction methods available for sea surface temperature anomalies themselves are those for the Pacific. Evidence is growing that anomalies of land surface moisture may also provide additional skill in the future.

There are multiple manners in which skill may be measured, and many centres have own favourites dissimilar to those used in other centres. Intercomparison between different models and forecasts therefore becomes difficult, to the extent that an intercomparison of skill levels between empirical and numerical models has only been achieved within limited parameters. Further, skill measures are often defined in a way that satisfies certain scientific objectives but fails to provide substantive information from the application perspective. Standardisation projects, sponsored by WMO and within the CLIVAR (Climate Variability – a Project of the World Climate Research Programme, WCRP), CBS (Commission for Basic Systems) and CLIPS areas, will hopefully address the issues. The project within CLIPS in particular is examining forecast verification from an application perspective. Skill measurement for probabilistic forecasts is more complex than for deterministic ones, and it is not possible to provide verification of single probabilistic predictions in the way users often request.

Despite the advanced technology behind SIP, forecast presentation methods remain basic in most cases, probably the most evolved approaches being those used in Australia. Further, although it is advisable to create a forecast using several models, as discussed above, individual centres currently tend to provide individual formats that make intercomparisons and consensus forecast building difficult. There is an on-going overall tendency for forecast presentations to merge towards probabilistic terciles, although other formats available include absolute predictions, probabilities of above/below normal, quintiles, deciles, and so on. The probabilistic tercile approach is useful from the scientific perspective in that it may well represent the current practical limit on predictability and that it facilitates both presentation and verification. Probabilistic terciles are not, however, always ideal from the application perspective. It is difficult to see how progress in the science may advance this position in the short term, and therefore improved ways of interpreting tercile information for applications need to be sought.

In October 2000, a meeting was held near Pretoria, South Africa, to review the progress of Regional Climate Outlook Forums (RCOFs), a major method for disseminating forecasts in the developing world that is discussed further below, and to make recommendations for future improvements to the system (Basher el al. 2001). Many of the issues covered above were also raised during that meeting and some important recommendations forwarded. Amongst these were included the need to develop an overarching research agenda and to examine and act upon the constraints that impede progress. Further there were calls for further investigation into downscaling methods, especially using RCMs, and for the development of consistent verification methods, including a revisit of all Forum forecasts so far in an effort to establish skill levels in a consistent and appropriate manner. Many of these issues are being now taken up under various Expert Teams (ETs) within the new CCl (Commission for Climatology) OPAG (Open Programme Area Group) structure.

1.3 Terms of Reference (b) – To survey and summarise, using appropriate case studies, the current applications and possible impacts of seasonal forecasts and climate prediction in agriculture, forestry and livestock management

Agriculture has been one of the application areas with the longest history with regard to SIP. Indeed it can be argued that phenological prediction methods originally developed several thousand years ago mainly because of agricultural considerations. More recently Gilbert Walker's work on prediction of the Indian monsoon that provided the initial scientific basis for ENSO was originally undertaken for agricultural prediction needs. Agricultural applications have continued to receive high profile and have become the basis for several national and international projects. A few of these projects are reviewed briefly in this section.

As an initiative of the UK Government, the Seasonal Weather Forecasting for the Food Chain project proved remarkably successful (Sherlock et al. 2001). Although undertaken in a country with relatively limited seasonal predictability, conclusions from three of the four sub-projects (focussing on field vegetables, sugar beet and tomatoes – apples provided to be the exception) were that value could be obtained from the predictions. In field vegetables, under which peas and baby leaf salads formed the major focus, most benefit appears to be within the frozen produce sector. Numerous operational decisions could potentially benefit in the growing of sugar beet, including various scheduling aspects as well as planning of agrochemical use, while tomato growers will benefit from integration of forecasts on a range of scales. Only in the apple growing and supply chain did there appear to be no forecast benefit. One important conclusion of the project deserves mention. It was concluded that optimal benefit was obtain through co-ordinated actions throughout the food chain based on the forecasts rather than through all those involved taking independent decisions.

One reason behind the success of the project was undoubtedly the close and extensive liaison between the climatologists and those on the food chain side (which covered all aspects from basic production though to retailing). Time was taken on both sides to understand the prime issues of the other and the resulting synergy generated an overall fuller interdisciplinary comprehension of the entire forecast-application path than is sometimes the case. In this regard the report notes that 'there is no substitute for forecasters and food chain business working in partnership to address the issue'. A second source of the success was the use of a decision model that could be readily interpreted on both sides. This model was based on 'Relative Operating Characteristics', ROC, which can be used to measure model skill as well as to establish optimal strategies for using the forecasts in specific applications (these strategies normally vary between applications) and the value potentially achievable (Harrison and Graham 2001). Recently Wilks (2001) has proposed an improvement to the ROC approach, although this has not yet been tested in projects.

The CLIMAG (Climate Prediction and Agriculture) Project is an international project initiated by START (Global Change System for Analysis, Research and Training - part of IGBP, the International Geosphere-Biosphere Programme), and linking with the WCRP and IHDP (International Human Dimensions Programme). It has the aim of applying predictions of climate variability on time scales of a month to a year to crop management and decision making in order to increase agricultural productivity from farm up to national scales. At an international meeting held at WMO Headquarters in September 1999 current activities in SIP and agricultural applications were reviewed and pilot projects building on existing experience and facilities proposed for Latin America, southern Asia and Africa (Sivakumar 2000). Many options on the prediction side were covered at the meeting, including the use of statistical weather generators as well as RCMs to provide the detail in predictions often desired by users.

CLIMAG projects in the three regions are still at a relatively early stage and the only detailed information available to the author is that related to one activity line in South Asia (Meinke, 2000). Case studies in Pakistan, Tamil Nadu and Bangalore have been undertaken in a collaboration between APSRU (Agricultural Production Systems Research Unit), the IRI (the

International Research Institute for Climate Prediction), Tamil Nadu Agricultural University, the IIS (Indian Institute of Science), PARC (Pakistan Agricultural Research Council) and IITP (Indian Institute of Tropical Meteorology). Climate input has been based on the APSRU Long Paddock system of developing statistics stratified by phases of ENSO not only for rainfall but also for a range of agricultural outputs. It is an interesting discussion over whether the term 'forecasting' can truly be applied to this approach – in CLIPS terms it falls more under the 'information' aspect - but there is no doubt about the potential benefits already demonstrated. Various scenarios and options can be simulated based on the estimated probability distributions produced which can then be presented to users within a framework that guides their decisions. The Project PI in the Final Report indicates that, through an active education programme combined with detailed data analysis, results have been obtained indicating the value of the approach, the gain of improved insight into the management of cropping systems in the region and the potential for further extension of the work. It is thought likely that additional value would be obtained given actual forecasts against which the background already developed could be developed.

The Long Paddock approach has been tested in a number of parts of the world, with project proposals submitted or under preparation for extension to further regions. An overarching concept proposal has also been developed under CLIMAG in which this approach would be extended to establish an international, interdisciplinary network that will quantify and implement adaptive responses to climate information within the world's farming systems christened *RES AGRICOLA* ("Farmer's business" in Latin), it is conceived as a network for farmers, scientists, policy advisers, extension specialists and other stakeholders concerned with connecting climate, agricultural science and decision making. Current seed financial support has been obtained from APN, START and NOAA-OGP.

The International Research Institute (IRI), an organisation that has been an important contributor to the CLIMAG project reviewed above, also has a programme of agricultural activities in various parts of the world, both within and without the CLIMAG umbrella. The following remarks are based on input from James Hansen of the IRI, and include conclusions drawn in a paper to appear (with many others of relevance to the WG) in a 2002 edition of Agricultural Systems Pilot studies in various parts of the world with various crops and cropping systems have indicated that, while it is still too early to be entirely specific about the potential value of SIP for agriculture, there is reason to be optimistic concerning future opportunities realised by further research. Indeed there is a growing body of evidence illustrating benefits obtained through appropriate responses to individual predictions. Five prerequisites for beneficial use of SIP have been identified: a) the requirement to address needs both real and perceived; b) the requirement to use viable decision options that are sensitive to climate variability and forecast content; c) the requirement that the forecasts themselves should address aspects amenable to viable decisions; d) the requirement that forecast information be communicated in an effective and appropriate manner; e) and the requirement that the process takes places within an environment of institutional commitment and favourable policies. Interestingly phenological methods, still utilised in several regions of the globe and often with higher priority perceived over modern SIP in many communities, satisfy all five requirements in many parts of the world.

Several approaches to the decision making process are under consideration at the IRI, including: the use of analogue years, perhaps based on an ENSO index; a modelling approach using historical data and based on Bayesian statistics; and approaches that educate as well as seek to understand the needs, perspectives and perceptions that permit decision makers to use all available information within a 'least regrets' framework. The common key to these decision methods is a substantive archive of climate and agricultural information.

Whereas the projects reviewed above tend to focus on operational agricultural decision-making, a further international project is focused more towards regional-scale agricultural planning. Funded in part by the EC, PROMISE is a collaborative effort between 13

European organisations, CPTEC, IITM, IMTR and LASG, to examine the potential for seasonal prediction and the benefits that would accrue in terms of management of water resources and agriculture. An equivalent second objective deals with climate change. The project focuses mainly on the monsoon regions and has a substantial modelling component, both climatic and applications.

PROMISE is concentrating on the incorporation of water balance and crop prediction models into SIP products from DEMETER. Delays to DEMETER have rippled through to PROMISE, although preliminary work is in progress for the Sahel (main annual crops) and India (groundnut). Decision processes are based on scenario development using the DEMETER ensembles interpreted through the applications models suite.

The above review is a far-from-complete survey of all activity. Not included have been, for example, the activities of CGIAR, although these are more focused towards climate change, nor the new WCRP-IGBP-IHDP GECaFS project, again primarily global change. The IGBP GAIM project is perhaps not currently relevant but may become so with its programme of blending of numerical components towards an integrated model of the Earth's biogeochemical system. Further activity might be encouraged should the recently established INSAM determine this to be a priority area of activity.

In summary, a number of different approaches to the key issue of agricultural decision-making given a forecast product have been addressed in the above projects. These range from the relatively straightforward least regrets approach, through progressively more complex modelling strategies via the ROC method which merges forecast verification and application information into a single decision making framework. One interesting outcome of the ROC method is that it can be used to demonstrate that more value is achievable through calibrated use of a set of probability forecasts than of use of an equivalent set of deterministic predictions. No final solution to the decision making issue has yet been determined, and this remains a priority area for research, but one common need is apparent in all approaches. That is the requirement in all decision methods for a substantial database of climate, forecast and relevant application information. It appears that use of SIP without such a resource could be less effective than might otherwise be the case.

1.4 Terms of Reference (c) – To review and recommend ways to use and disseminate optimally the seasonal forecasts and climate predictions in operational agriculture with emphasis on user needs especially in the tropical and subtropical zones

Prior to the 1997/98 El Niño event, forecast distribution was limited to a relatively small number of organisations, with distribution often by traditional mail or fax. Examples included the UK Met Office predictions for Northeast Brazil and the Sahel, NCEP's CPC prediction maps for the USA and the services provided by numerous eastern European NMHSs. In all cases the prime basis for these predictions was empirical. Formats varied substantially, although in most cases these formats were discussed with end users.

Two major dissemination issues changed irreversibly as a result of the El Niño. Many organisations, NMHSs, research centres and universities, recognised that their climate change modelling efforts could be used (and normally had already been tested) for El Niño predictions. The rapidly expanding Internet provided the ideal delivery vehicle for numerous predictions from these centres. Often uncoordinated, these broadcasts were sometimes contradictory, while some were alarmist. The flood of information confused many potential users, as well as the media. Matters quietened down as the El Niño changed into the La Niña but the Internet has remained central to dissemination of predictions from many centres (a partial list includes the UK Met Office, CPC, the Met Service of Canada, the IRI, ECMWF, BoM, SAWS). In some cases Internet delivery is protected for confidentiality or commercial reasons.

Internet delivery is inappropriate in all parts of the world, but technical solutions, such as those used in the RANET project, are being used to by-pass the probleMs Not only does this developing technology permit rapid delivery of forecasts, as well as access to historical data, in remote locations, it is also now possible to receive the information as computer files, the only barrier being access to a power supply. While electronic delivery methods will change, and while more traditional delivery methods may not yet be transplanted in all cases, it is difficult to see most future dissemination being based around anything other than rapid electronic methods.

One other source of dissemination will remain central however, even if the Internet delivers the initial information. That is the communications media of the press, radio and television. Not only may the 'gentlemen of the press' deliver the forecast itself, they can also be expected to interpret the forecast in terms of actions. It is critical to ensure through continuing contact and education programmes that the media provides the conduit for responsible information critical to successful application of predictions. RANET provides access to remote communities whose interpretation of the forecast information might be incorrect without the necessary support from the media.

The second dissemination change at the time of the El Niño was the (coincidental) introduction of Regional Climate Outlook Forums (RCOFs), the pilot series being run in southern Africa but others, motivated by the El Niño, rapidly appearing in South and Central America and the Caribbean, other parts of Africa and South-East Asia and the Pacific. RCOFs help perform a number of functions – in bringing together a substantial number of climatologists, intermediaries and end users, decision makers and the media they provide an ideal platform for education, and multidisciplinary discussion and co-ordination. Based on the principle discussed early that the highest quality predictions are provided by combining different forecasts, consensus predictions are created at RCOFs using inputs from all available models. Open discussion of the consensus assists in decision making in many application areas, including agriculture. Sometimes follow-on meetings at national or regional levels are held to assist dissemination and interpretation. The Internet and the media also play key dissemination roles in association with the NMHSs. RCOF products, interpreted nationally by the NMHSs, are usually viewed as the most authoritative statements available. RCOF are expensive to hold, and virtual Forums are now held in some regions. A major review meeting of the RCOFs, stimulated in part by the cost issue and held in late 2000, and attended by climatologists and applications experts, recommended that the Forums continue and that further development and research be focussed on the needs of SIP delivery through the RCOFs.

An Intercommission Task Team (ICTT) of WMO, on which CAgM is represented, is examining the possibility of establishing Regional Climate Centres (RCCs), which would be tasked with regional priorities in prediction delivery, data set creation, research, education, etc., in order to provide a core of expertise not available in all individual countries. If established these RCCs would provide a natural conduit for forecast information and, in collaboration with regional experts, for forecast interpretation. It is likely that there will be some link between the RCCs and the RCOFs. Regional activities which already handle some of the envisaged roles of RCCs include ACMAD, AGRHYMET and the DMCs in Africa, and ASMC, ADPC and APCN in South-East Asia.

The multiple and independent delivery routes that were characteristic in 1997/98 are thus becoming more integrated into recognised and co-ordinated channels, although many SIP producers still provide information as a one-off via the Internet. There are the RCCs, the RCOFs, various regional initiatives, the work of ASPRU, CLIMAG, RES AGRICOLA, and others. There is perhaps a need to consider the extent to which further integration of activities might take place – for example should the proposed RES AGRICOLA, if implemented, be co-ordinated in any way with the RCCs, again if implemented, in search of a more complete solution for agriculture.

The question of the use of SIP has been dealt with in other parts of this report, including the issues of multiple and inconsistent presentation formats and of verification. Under the recently-revised structure of CCl, three OPAGs have been created, two of which deal with the fundamental data issues necessary for the provision of climatological information and predictions. The third, Climate Applications, Information and Prediction Services, covers Expert Teams (ETs) that should provide outcomes of concern to the agricultural sector. The ETs include:

- Research Needs for Intraseasonal, Seasonal and Interannual Prediction, including the Application of these Predictions – the main task here is to provide a research vision covering prediction as well as applications to guide developments over the next few years.

- CLIPS Operations, including Product Generation, with Emphasis on Countries in Need – to examine delivery issues, such as formats and best practices, to ensure optimal product delivery to users.

- Verification – to consider verification more specifically from the user perspective and to propose methods that will provide transparency and assistance in decision processes.

- Capacity Building – activities throughout the climate and user communities.

- End User Liaison - issues relating to the use of SIP, including examination of decision processes, and contact between climate and user communities.

In addition the OPAG will include Rapporteurs on Climate and Agrometeorology and on Regional Aspects of Climate Services.

1.5 Terms of Reference (d) – To propose applications for use of seasonal forecasts and climate prediction for early warning of extreme climatic events

The term 'extreme climate event' is one that is used frequently but one that can be misinterpreted. In basic terms it might be defined as an event that, in terms of the historical record, has only a 10% or perhaps a 5% probability of occurring. In terms of this definition the sea surface temperature anomalies observed in the central tropical Pacific Ocean during the 1997/98 El Niño event were certainly extreme. However one extreme event does not necessarily lead to another. For example El Niño is frequently associated with heavy rainfall along much of the South American coast (which certainly happened in 1997/98 but may not necessarily have been extreme in terms of the above definition) and drought in southern Africa (rainfall tended to be close to average in 1997/98). In reverse the intense southern African drought of 1991/92 coincided with a mild El Niño event which may not itself have been extreme. Further 'extreme climate events' are sometimes interpreted in terms of an impact, say a poor crop, when in fact the climate itself has not been extreme. Finally, in impact terms, what might be considered extreme in one country could produce limited difficulties in a country with more resilience. Improved agricultural techniques also protect against climate extremes and adjust perceptions. A clear definition, or an alternate phrase, might be useful.

Nevertheless, the issue is an important one as most cropping and husbandry systems are able to cope with limited climate variations, but may not when stressed with less probable events, especially when other stresses from environmental or social systems are also present. Examination of the skill of seasonal predictions has indicated that the best skill is focussed into the outer parts of a predictand's range, say the outer boxes in a tercile system. Forecasts for conditions close to the statistical normal tend to have relatively limited skill. Happily, this aspect of the forecast system and of the user requirements conveniently coincide.

Forecasters have made some attempts to convey skill/extremes information to users. CPC, for example, normally provide no forecast except when the predicted distribution differs sufficiently from climatology. A comparable system is employed by ECMWF. The IRI, in addition to providing predictions in a tercile format, also attempts to assess probabilities of future rainfall and temperature events that fall beyond the 15th percentiles of the historical records. The Met Office masks out predictions where tests have indicated that skill falls below specific levels.

In certain cases the more extreme events also provide opportunity for longer-lead predictions, at least if they are associated with ENSO. The 1997/98 ENSO and its impacts were predicted by some, not all, models at a lead that gave chance for some preparations to be made. However it has been pointed out that the predictions were only made once the event had already begun. No test of subsequent system improvements has yet been made but longer-lead predictions are likely to be tied to ENSO only for the foreseeable future.

The more extreme climate events, capable of disturbing agricultural systems without contributions from other stressors, provide opportunities for examining application approaches not only during the events but also in preparation and education activities. It may be easier to develop applications initially around such events, leaving approaches to less extreme anomalies for later progress.

1.6 References

Sherlock, J., R. Clements, M. Davey, J. Fenlon, R. Graham, M. Hall, M. Harrison, C. Knott, G. Marston, R. Seaby, R. Sylvester-Bradley and D. Wurr. 2001. Seasonal Weather Forecasting for the Food Chain, UK Department of Trade and Industry Publication DTI/Pub 5232/4k/2/01/NP.URN 01/520, 43pp.

Harrison, M. S. J. and Graham, N. E. 2001. Forecast quality, forecast applications, and forecast value: cases from southern African seasonal forecasts, WMO Bulletin, 50, 228.

Kimura, Y. 2001. A Survey on the Present Status of Climate Forecasting. Available from the WMO Secretariat on CD-ROM: World Meteorological Organisation Commission for Climatology, Thirteenth Session, Geneva 21-30 November 2001.

Meinke, H. 2000. Management Responses to Seasonal Climate Forecasts in Cropping Systems of South Asia's Semi-Arid Tropics. APN Report 2000-017, 25pp.

Basher, R., C. Clark, M. Dilley and M. Harrison. 2001. Coping with the Climate: A Way Forward. Published in two parts. Summary and Proposals for Action, IRI Publication IRI-CW/01/2, 28pp. Preparatory Report and Full Workshop Report, IRI Publication IRI-CW/01/1, 168pp.

Sivakumar, M.V.K. (Ed.) 2000. Climate Prediction and Agriculture. Proceedings of the START/WMO International Workshop held in Geneva, Switzerland, 27-29 September 1999. Washington DC, USA: International START Secretariat.

Wilks, D.S. 2001. A skill score based on economic value for probability forecasts. *Meteorological Applications*, 8, 209-219.

Further Reading

Barnston, A. G., M. H. Glantz, and Y. He. 1999. Predictive skill of statistical and dynamical climate models in SST forecasts during the 1997-98 El Nino episode and the 1998 La Nina onset. *Bull. Amer. Meteor. Soc.*, 80, 217-243.

Buizer, J. L., J. Foster, and D. Lund. 2000. Global impacts and regional actions: preparing for the 1997-98 El Nino. *Bull. Amer. Meteor. Soc.*, 81, 2121-2139.

Landsea, C. W. and J. A. Knaff. 2000. How much skill was there in forecasting the very strong 1997-98 El Nino? *Bull. Amer. Meteor. Soc.*, 81, 2107-2119.

NOAA/OGP. 1999. An experiment in the application of climate forecasts: NOAA-OGP activities related to the 1997-98 El Nino event. *NOAA/OGP Report*, 134 pp. [Available online from http://www.ogp.noaa.gov.enso/retro/ensodoc.htm]

CHAPTER 2

THE USE OF SEASONAL AND CLIMATE FORECASTING IN OPERATIONAL AGRICULTURE

A. Kanga
Direction de la météorologie
BP 208 Brazzaville
Congo

2.1 Introduction

Weather and climate play an essential role in many human activities such as agriculture, energy production, wildlife management, health services and other sectors. In recent decades, science and technology have given us a better understanding of climate and weather. There is now a wide range of weather and climate observations and forecasts which, once taken into account, can considerably help to control and reduce the impact of extreme climate events. These observations and forecasts must be disseminated to users to help them establish policies and strategies for planning their activities. The means used to make this information available determines whether or not it is available in time for users to make timely decisions.

Seasonal weather and climate variations have a significant impact on society because of their effects on water resources, environment and health, and more directly on agriculture and food security. These variations can significantly diminish agricultural yields. In recent decades, science and technology have given us a better understanding of climate and weather. Specifically, knowledge of the climate system, relationships between all climate system components, the role of the oceans in the distribution of climate elements, the discovery of the El Niño phenomenon and its attributed teleconnections. In particular the 1997-98 El Niño event, which had a socio-economic and environmental impact in different regions of the world, especially in Western Africa, have led to a breakthrough in climate prediction. These impacts were very clear in the field of agriculture, food security, water resource management and health. There are now a wide range of weather and climate observations and forecasts that can considerably help to control and reduce the impact of extreme climate events. However, to date, all of the seasonal forecasting models used have a margin of error. There are several reasons for these limitations. Some of the errors are caused by the data used for producing the models (interpolated data is often used). Faults in the models themselves are sometimes to blame, as are the limitations of predicting the atmosphere, which can be predicted only up to a certain point.

This observation, however, should not discourage research into seasonal forecasting. Neither should it deter us from making nor disseminating forecasts since making no forecasts at all is potentially disastrous.

This paper presents a number of advances made in the field of seasonal forecasting and some of the products available for use in agriculture at the African Centre of Meteorological Applications for Development (ACMAD), which for four years has been making and transmitting a forecasts, at the beginning of the rainy season, on how the coming season will develop, in collaboration with its partners and the meteorological services of Western Africa. This paper also presents a tried and tested means for disseminating meteorological and climatological information and products.

In recent decades, the Sahel has experienced several years of significant rainfall deficits, which severely diminish agricultural production and water reserves. To help reduce the affects of various droughts, ACMAD, in collaboration with its partners, established PRESAO, which is derived from the French for '**PRE**vision **S**aisonnière en **A**frique de l'**O**uest' (seasonal forecasting in Western Africa). PRESAO was designed for capacity building in the area of climate prediction and for providing consolidated forecasts in the West African subregion on the basis of sea-surface temperatures.

The main objective of PRESAO is to create food security and give early warnings by providing data or information on seasonal forecasts for making decisions in the field of agriculture, water resource management and other sectors of activity.

Various users of climate information and forecasts have been identified, such as the following: rural development and agricultural services, farmers, NGOs, decision makers, agro-industries, water resource management and health services.

Of all of these human activities which use climate information and seasonal forecasts, agriculture is probably by far the biggest user. Indeed, climate variability has been, and will continue to be, the main cause of variations in total food production, particularly in semiarid tropical zones. In some countries, 80% of the variability in agricultural production is caused by climate variability.

For agricultural purposes, there are numerous advantages of having a precise seasonal forecast of the climate conditions. Timely forecasts enable farmers to plan their work accordingly and to take full advantage of favourable conditions. In some cases, an early, less reliable forecast can be more useful than a late, but correct, forecast.

2.2 Seasonal Forecasts

Seasonal forecasts give users a general idea of how the season will develop and generally cover a period of three months, giving an overall, regional picture, without spatial or temporal details. Therefore, a dry spell of 10 days or more in the middle of a forecasted rainy season, which would have numerous consequences, would not be detected. Historical data on the season for the forecast parameter are presented in three or five categories. The forecast will establish which category is most likely to occur. When applied to agriculture, this forecast allows farmers to select crops according to their water requirements during the growth cycle.

Following the encouraging results of the PRESAO process, ACMAD helped train climatologists within the framework of the Greater Horn of Africa Climate Outlook Foras (GHACOF), for which the Nairobi DMC is responsible, and the Southern Africa Regional Climate Outlook Fora (SARCOF), for which the Harare DMC is responsible.

Similarly, ACMAD and its partners are going to launch the first climate outlook forum for North Africa (PRESANORD) in Algiers in April 2002 and one for Central Africa (PRESAC) in Brazzaville, Congo in August 2002.

2.3 Medium-range Forecasts: Dynamic Downscaling

It is now possible, using global climate forecasts with wider temporal and spatial scales, to develop products with fine spatial and temporal scales that are more appropriate to the specific needs of agrometeorology. Indeed, limited area climate models whose boundary conditions are provided by general circulation climate models may be used for medium-term regional studies. This process, which is known as dynamic downscaling, makes it possible to understand small, local scales from large-scale information. Such information is complementary to the seasonal forecast. It makes it possible to regularly follow up the various parameters for 5 to 10 day periods so as to improve agricultural planning. It is thereby possible to predict the dates of the beginning of the rainy season, dry spells and hot periods. Similarly, it makes it possible to establish various thresholds for some parameters such as the number of days of rain reaching or exceeding certain levels or the water balance for developing strategies for irrigation or fertilizer application.

2.4 The CLIMAG Project

The 'Climate and Agriculture' project (CLIMAG) is a START (Global Change SysTem for Analysis Research and Training) initiative in collaboration with various sponsors (IGBP, IHDP and WCRP). The aim of the CLIMAG project is to develop a network for harmonising climate forecasts to reduce the impact of global climate change on agricultural production. The West African project (CLIMAG-WA) component was launched in Bamako, Mali in April 2001 and was financed by EC/ENRICH (European Network for Research on Global Change).

The project calls upon the services of multi-disciplinary teams for actively combining the expertise required in disciplines ranging from climatology and agronomy to production system modelling. Bearing in mind its experience in climate forecasting, ACMAD was chosen as a partner

The aim of the CLIMAG-WA project is to help optimise and harmonise efforts made in the fight against food insecurity and the vulnerability of ecosystems resulting from the combined effects of global change, damage to resources and seasonal climate variations in Western Africa.
To meet these objectives different approaches will be adopted:

- The assessment of the performance of the seasonal forecasting currently used in Western Africa in order to understand the agro-ecosystem's response to climate variability and evaluate the possibility of integrating early warnings into the seasonal forecast.

- The downscaling of regional seasonal forecasts to a subregional and field scale.

- The use of crop simulation models and analysis systems that have already been tested in the subregion for identifying and assessing the actual possibilities of downscaling climate forecasts.

During the seminar to launch the project in Bamako, a list of available data bases was presented along with specific experiments carried out by various partners in the subregion. To improve how climate variations are adapted to agricultural production, tasks are assigned to each partner.

In view of its experience in climate forecasting, ACMAD should search for new techniques for seasonal forecasts made on a finer spatial and temporal scale (subregional and field), in collaboration with its partners, and evaluate the performance of the seasonal forecasting used in Mali.

To accomplish these tasks, ACMAD has trained two people in dynamic downscaling techniques and has purchased high-performance computer equipment. At present, dynamic downscaling is being tested *a posteriori* at ACMAD for calibrating the model with a view to its future application.

Development of an optimal system for the dissemination of meteorological and climate information: the RANET system.

At present, Africa is still the continent with the fewest information and telecommunication systems. Although the problem appears to have been solved in major cities by a whole range of up-to-date media resources, from the Internet to mobile phones, it cannot be denied that the rural areas, which stretch over most of the continent, do not appear to benefit from this array of information sources, and adequate means barely exist for transmitting information. In rural areas, information still often circulates through word of mouth and current means are not yet available. Owing to isolation and poor roadways, the written press often arrives in the rural areas days after its publication. With regard to television and radio, the latter is increasingly broadcast on the FM band, so coverage rarely exceeds a radius of 50 km. Furthermore, running costs, such as the purchase of batteries, are a set back for rural communities.

Agroclimatic and environmental information, particularly on precipitation, is essential data for agropastoral activities and more generally for all economic activities. It makes it possible not only to plan several activities, but if early warnings are given, the appropriate measures can be taken to reduce the often negative impact of climate extremes. The progress made in climate forecasting research has now made it possible to predict a number of climate extremes and their impact on society with a certain degree of reliability. This information must be made available and accessible at the right time and place. The means currently used to disseminate it are the state media, such as radio and television, and in some cases newspapers, all of which are state-controlled. While there are some independent newspapers that include weather information, it is above all the state media that provide information specifically relating to climate, the environment or the follow-up to a drought. Owing to the lack of means available to the state for radio and television broadcasting, the rural population receives the information with great delay, for several reasons. First, only on rare occasions do the media provide such information because of their programming schedules. When they do, people in rural areas are not tuned in, either because of the scheduling or because they cannot afford batteries. Also, such media use foreign languages that are not understood by the rural population. In many cases, the target population simply does not receive the information in a timely manner. People in rural areas are thus generally caught completely off guard when natural disasters occur.

The aim of the RANET system (**RA**dio and Inter**NET**) is to make meteorological information and products accessible and available to rural communities. It was designed to fill a void between meteorological information producers and rural end-users. In 1997, the Sahel suffered a drought following the El Niño event. As early as February of that year, some weather centres had already forecast this El Niño event and had drawn up strategies to deal with the consequences. Unfortunately, since people in rural areas in the Sahel, in particular in Niger, had not received any information, no steps had been taken. Many herds were decimated owing to a lack of pasture or water. In October 2000, a month when it hardly ever rains in Niger, a farmer in the Say region who was drying his crop was caught unprepared by the rain, whereas rain had been forecast in that region. Unfortunately for him, he had not received this information. The RANET project was set up to meet the urgent need for meteorological information among rural users in isolated deserts, mountain areas or flood zones. The idea emerged in 1997 when Dr Mohamed Boulahya, the Director-General of ACMAD, met people from rural areas who expressed their wish to be informed of the follow-up to a drought. The project's objective is to end the isolation of rural African communities (such as herders, farmers and fishermen, etc.) and to use rural community radio programmes to involve them in meteorological data observation and use. The system makes use of new communication technologies such as the Internet and the WorldSpace system for the digital radio reception of satellite transmissions.

The RANET distribution chain comprises the following steps (see Figure 2.1):

(a) Development of meteorological and climatological information (observations, maps, images, bulletins, etc.) by ACMAD, the national meteorological and hydrological services (NMHSs) and their partners;

(b) Multimedia formatting on the RANET 2000 server;

(c) Data transmission to the WorldSpace uplink station for digital broadcast via the AfriStar™ satellite throughout Africa;

(d) Reception and downloading of data onto a PC using a WorldSpace digital radio or a WorldSpace adapter kit;

(e) The received data may be for final use (farmers' or fishermen's associations) or may be used by a specialised centre such as a weather station, community radio station, hospital, school or any Integrated Community Centre for Information for Sustainable Development (CID);

(f) The information is adapted (extension activities, translation into the local language, the addition of local information, etc.) and "put on the air" for local FM rebroadcast (range of 25 to 50 km) using a solar powered-radio;

(g) Final reception by the rural communities, using solar or crank-powered radios (FreePlay) with a 30-minute renewable listening time;

(h) E-mail messages are sent to an Internet centre via the Portable Ground Station-Volunteers in Technical Assistance Satellite (PGS-VITA Sat) system.

The information transmitted by RANET is in alphanumeric, satellite photographic and audio-visual formats.

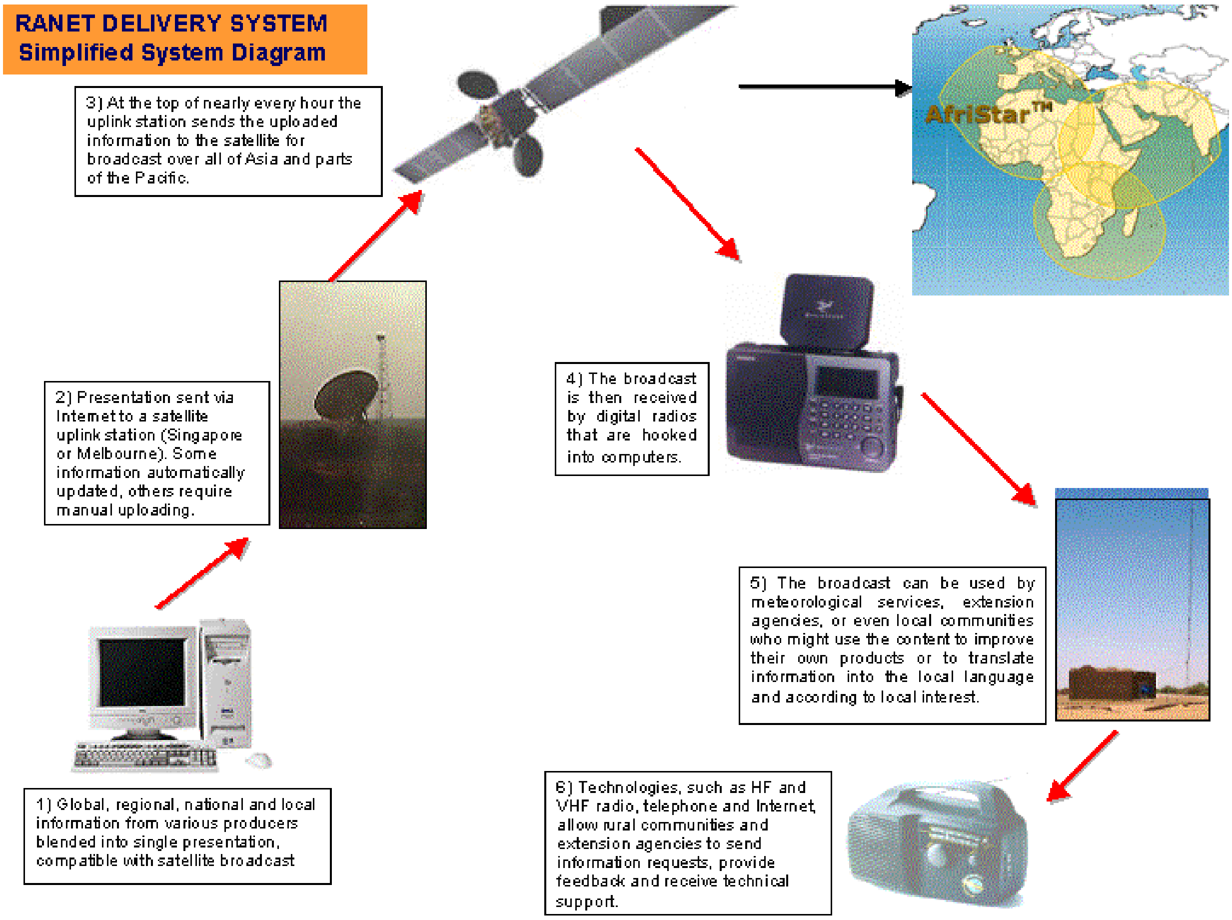

Figure 2.1 Diagram of the RANET Delivery System

Although the RANET system was initially designed to broadcast climatic information, many bodies (including FAO, VITA and HKI) now use it to disseminate their products. RANET has thus become a model of cooperation among several bodies working against isolation and towards training and information in rural communities. Therefore, the content of the broadcasts cover several fields. The rural population in Bankilaré, a village with an ACMAD pilot project on the edge of the desert to the north-west of Niamey in Niger near the Malian border, has changed its farming and grazing practices and its way of life thanks to the RANET project. Where houses used to be built in wood, new construction materials are increasingly being used, particularly earth bricks. Herdsmen who previously ventured no further than 20 to 25 km from the village for fear of being cut off can now graze their livestock up to 50 km away without any risks. The RANET project has changed the way of life among the rural population of Bankilaré. Many other projects are currently under way at sites in Niger and other African countries. Farmers' village associations are conducting these projects with a view to benefiting from agroclimatic information in the same way as the population of Bankilaré. The RANET system has made rural populations capable of dealing with drought by changing their habits.

The RANET system currently has numerous advantages. First, the system is user-friendly, which is why it has been accepted by the rural population. Its low cost makes it accessible to most village organizations, which pool resources to buy it. Its sustainability is thus ensured by the rural population, which could take over responsibility for the system from donor agencies and institutions. The only drawback of the system is that information flows in one direction. However, this has been partially addressed by the PGS-VITA system, which allows for email messages to be sent from information users to producers.

Several technical missions have concluded that RANET is the appropriate answer to the problem of ensuring communication among meteorology professionals and between them and isolated users in rural areas. In its resolution 6.4.12 adopted at its twelfth session, held in Geneva from 29 November to 8 December 2000, the WMO Commission for Basic Systems called for RANET to be extended to Asia and Latin America, in the following terms: "The Commission noted with interest the development of RANET (Radio and Internet for the communication of meteorological, hydrological and climate-related information) project, which is a cooperative effort initiated by ACMAD in order to improve access to climate and weather-related information throughout Africa." Similarly, the technical conference of the WMO Commission for Climatology, held in Geneva from 21 to 30 November 2001, emphasized the need for the closest possible cooperation with the beneficiaries of climatological services, and made the recommendation to 'Maximize the exploitation of best technologies (e.g. RANET)'. Therefore, the prospects are quite good. To ensure that the system is effective, first, all meteorological services must be incorporated, observation points must be developed and strengthened and a system must be set up which allows users to take part in this process, by turning them into producers of basic information. The use of the PGS-VITA station has already made it possible to link rural communities with meteorological centres. Since the RANET system is a model for cooperation, it will also be necessary to ensure that Community Information for Development Centres are set up. Such centres will include the tasks of weather, climate and environmental observation stations. Once the rural community masters the system and recognizes its worth, the main thrust of the project should shift to its meteorological component, by seeking meteorological products, information and data of use to the rural community.

CHAPTER 3

IMPACT OF THE El NIÑO PHENOMENON ON CROP PRODUCTION IN THE ARGENTINE PAMPEANA REGION

G.O. Magrin, M.O. Grondona, M.I. Travasso, D.R. Boullón,
G.R. Rodríguez & C.D. Messina
Instituto Nacional de Tecnología Agropecuaria
Instituto del Clima y Agua
Argentina

3.1 Introduction

One of the main sources of interannual climatic variability is the ENSO phenomenon (El Niño-Southern Oscillation) that refers to changes in the sea-surface temperature in the area east of the Equatorial Pacific (El Niño in warm years, La Niña in cold years) and it is associated with changes in gradients of atmospheric pressure and wind patterns in the Equatorial Pacific.

In southeastern South America, the signs of an El Niño event are manifested with above-normal winter temperatures and an increase of precipitation during the November-February period. Conversely, La Niña events are associated with below-normal winter temperatures and below-normal precipitation in the June-December period.

In this report, the impact of climatic variability related to the ENSO phenomenon is quantified on the production of wheat, corn, sunflower and soybeans in the Pampa region of Argentina. The study is based on the analysis of historical yield, production, sowed and harvested area at a national and regional level, and the historical precipitation, temperature and radiation.

3.2 Phases of the ENSO Phenomenon

Several alternative definitions of ENSO exist, mostly based on the patterns of atmospheric pressure or in the anomalies of the sea-surface temperature (SST) in the tropical Pacific Ocean, or a combination of both. In this report, ENSO is categorized according to an index developed by the Japan Meteorological Agency (JMA). This index is based on the SST anomalies in the Pacific Tropical between 4°N-4°S and 90°W-150°W. If SST anomalies were at least 0.5°C or greater during six consecutive months, the event was characterized as an El Niño or warm event. Conversely, if SST anomalies were at least -0.5°C or less, the event was characterized as La Niña or cold event. Period with SST anomalies in between +0.5°C and -0.5°C were considered neutral events.

3.3 Analysis of National Level Yields

The impact of the different phases of the ENSO were analyzed on the national yields of corn (1902-1995), sunflower (1919-1995), soybeans (1941-1995) and wheat (1902-1995) based from the official statistics of the Secretary of Agriculture of Argentina. The historical yield series was corrected for trend (technological changes) by applying a polynomial fit of the data, then the differences were calculated (deviations) and they were associated with the various ENSO events (El Niño or La Niña) and Neutral.

For corn, 15 of the 20 El Niño events (75% of the cases) the yield was the same or greater than average, while for La Niña events, 17 of the 23 registered events (74% of the cases) the yield was lower than average, and in the neutral years the behavior was variable. The largest deviations were observed in La Niña events with yield reductions that reached 56%, and in the El Niño events the largest yield increase was 36%.

For soybeans, the biggest impact was for La Niña events where the yield residual was negative in 71% of the events. For El Niño and neutral events, the yield deviations were positive in 58% and 62% of the cases respectively.

Sunflower was the summer crop that presented the smallest association among the yield residual and the ENSO phases. For El Niño events, similar higher and lower yields to the mean frequently appears, while during La Niña events, 59% of probability exists of obtaining higher mean yields, behavior that is opposite to the soybeans and the corn.

In the case of wheat, only in 13 of the 23 La Niña cases (57%) was the yield was lower than average while for both the El Niño and neutral events, they presented same frequency of higher or lower yields to average.

3.4 Area Abandoned

The largest impact of the ENSO phases on area abandoned occurs on corn, which was significantly larger during La Niña events that in El Niño evevts. During El Niño events, area abandoned in the north-central portion of the Pampa region did not surpass 20%, with lower values of 10% in the main production area. The largest losses were located in southwestern Buenos Aires provinces and the Pampas, with values surpassing 50%. During La Niña events, although the losses increased in the whole region, the effect was more pronounced in the provinces of Córdoba, Santa Fé and Entre Ríos.

For sunflowers across the main production areas of the nation, they were not significant differences in the area abandoned related to the ENSO phase. Only the provinces of Entre Ríos and some of Córdoba, Buenos Aires and La Pampa, was there significantly more area abandoned during La Niña events.

For wheat, there was little correlation, with only significant differences occurring in the Santa Rosa districts and Pigue, where the area abandoned was significantly larger in La Niña events.

3.5 Analysis of Precipitation

Monthly precipitation was analyzed for the years from 1910 to 1995 for 39 rain-gauge stations located in the region. The precipitation was averaged for two months starting from August-September of the year in that the phase begins until May-June of the following year. The analysis evaluated if precipitation amounts were higher or lower than normal during El Niño and La Niña events, respectively.

If ENSO did not influence precipitation, there would be no change in the distribution of occurrences in the tercile categories of below normal, normal and above rainfall. This distribution would remain at 33,3% (one of every three years) for all three categories. However, if the ENSO phenomenon influenced precipitation, there is an increased possibility of having above or below rainfall during El Niño or La Niña events, respectively. As an example, assume that a value of 2 indicates that the rains would be higher or lower in 2 of every 3 years (high to 66% its occurrence probability). In this paper, this is represented as the sign of the phases of the ENSO in the Pampa region, expressed as risk of obtaining higher or lower precipitation than normal during El Niño and La Niña events.

During El Niño events, a influence weakly appears in September-October, October-November in the north and southeast of the region. In November-December, the influence increases with high risk of obtaining above-normal precipitation in Córdoba, almost all of Santa Fé, La Pampa and north and southwestern Buenos Aires. In December-January, the risk of obtaining above-normal precipitation remains in the western half of the region. During January-February, the influence practically disappears in most of the region (near normal rainfall). In February-March, the influence appears again, in western Entre Ríos and center-west Buenos Aires with high risk of above-normal precipitations. In March-April, the influence is restricted to the north of Entre Ríos, Santa Fé and Córdoba, while from then on (April-May and May-June) there were no important correlations observed.

In La Niña events, the influence also begins in September-October in the north of the region, but it extends quickly and already in October-November most of the area registers a high risk of occurrence of precipitation. In November-December, the influence is high and is extends to the whole Pampa region, with risks of up to 2.8 (that is to say 93% of probability) of registering above-normal precipitation. In December-January, the risk of registering droughts is delimited to two strips that cover the central Córdoba and southern Santa Fé and southwestern Buenos Aires. As same as in El Niño events, during January-February, there is not any signal, with only an area detected in southeastern Buenos Aires with a possibility of registering above-normal precipitation. In February-March, the risk of drought reappears in the north, while in March-April, the signal increases the risk of below-normal precipitation in most of the area. Starting from April-May the signal begins to disappear, being restricted to a small strip in the east.

3.6 Relationship between Yields and Climatic Variability

The sign of the phases of the ENSO, expressed as risk of having above-normal precipitation in El Niño events and below normal in La Niña events, was more intense and more persistent in the La Niña phase. In this case the precipitation would be low in the spring (October, November and December), normal part of the summer (January and February) and again low toward the end of summer and the beginning of autumn (March and April). This pattern of precipitation would lead to periods of drought of different intensity during the spring, summer and autumn, since the period of increased water deficit takes place towards the end of the year. The subsequent rains would be insufficient in alleviating the drought, but water defects would increase during the autumn again.

During El Niño events, the signal (above-normal precipitations) begins coinciding with the end of the spring, the beginning of summer (November, December and January) and it is clearer in the center-west of the Pampa region.

Of the crops analyzed, corn was the one that presents the most marked associations with the phases of the ENSO, as much in yield as in area abandoned. The probability of obtaining higher yields increases during El Niño events and decreases in La Niña events which coincides with the possibility of occurrence of above and/or below precipitation to the El Niño and La Niña events respectively. The water availability at flowering is important for the determination of the number of grains. However, as the same as in other species, the initial growth modifies the potential production, as the favorable conditions in the beginning of the cycle is associated with higher production.

Although the results indicate that the probability of obtaining increased yield in El Niño events or decrease yield in La Niña events is greater than normal across most of the region and that this the result is associated with greater water availability (intensity and persistence of dry or humid periods), there are two important aspects:

1. The most favored subregion during El Niño events does not coincide with the subregion affected in La Niña events.

2. The probability of having low yields during La Niña events is larger than the one of having high yields in El Niño events.

These two aspects together with larger area abandoned during La Niña events indicate that the biggest impact during La Niña events is on the national corn production.

For soybeans, the impact on yields during the cold phase (La Niña) is marked by a high probability of obtaining below-normal yields in most of the main production region (northern Buenos Aires, Santa Fé and Córdoba). During El Niño events, on the other hand, there is only a possibility of obtaining higher yields in isolated areas. For this crop, the water deficiency is the main limiting factor on yields, however once reproduction (? Cutleries) the water requirement of the crop reaches a maximum whose level that would be defined by other restrictive factors.

For wheat, it was found that in the south-southwestern portion of Buenos Aires, an important production area, yield varies during El Niño and La Niña events. The biggest probability of obtaining yield increases in El Niño events or decreases in La Niña events would be associated with the occurrence of more or less precipitation during the month of November, coincident with the pre-flowering stage that is highly sensitive to the water availability.

For sunflowers, the behavior is opposite, where there is a larger probability of obtaining low yields in El Niño events and higher in La Niña, with more marked effect in El Niño events. This crop is adapted to semi-arid areas and is very sensitive to the excessive water and lack of radiation.

3.7 Some Considerations on the Use of Seasonal Forecasts in the Agricultural Sector

While we know the effects that ENSO has on agricultural production, the current capacity is to predict its occurrence. The current opportunity is to adjust the agricultural decision-making process to the climatic conditions.

However, the effective application of the climatic forecasts to the agriculture of a region does not only depend on the accuracy of the forecast and of the knowledge of the vulnerability of the sector, but rather also:

1. Objective options should exist to translate the knowledge of the future climate in practices that improve the decisions, and

2. It is necessary to know the possibility, ability and bias of those who make decisions to modify their plans based on the available information.

The existence of objective options to adapt the production to the ENSO event is related with the use of tools that allow it to be evaluated alternatively. For example, if a La Niña year is predicted it is known that the precipitation will be below normal and it will especially affect corn and soybean crops. What to do then? Although the knowledge and the intuition allow to infer a series of alternative possibilities (for example to reduce the sowing density or the application of fertilizer) it won't be possible to evaluate all the possible options and their combinations (for example, alternative crops, sowing date, planting density, and fertilizer application).

At the moment, we have crop models that predict yields under various climatic conditions and they can offer different scenarios of how to optimize yields and economic revenues according to the predicted environmental characteristics. Several of these models have been adapted to the Pampa region, providing mean errors of estimate of the yield of 8% (wheat), 13% (soybean), 14% (corn), 18% (sunflower) and 8% (barley).

The adoption of the good alternatives according to the predicted climate will depend on the "possibility", "ability" and "bias" of who makes the decisions to change their plans. For example, if the forecast of tendencies announced the occurrence of an El Niño or La Niña phase with enough anticipation, the possibility would exist of adopting any option, including the one of changing crops. However if the forecast was known later to give certain options like changing crops, using other varieties or longer season hybrids or advancing the sowing date would be impossible to consider.

Lastly, it will be evaluated which the economic value of a forecast of tendencies for the agricultural sector. In this sense there are two possibilities:

1. That the forecast is good: in this case the economic value will arise of the difference among the obtained revenues using the good handling alternatives and the prospective revenues without using additional information.

2. That the forecast is erroneous: in this case it is necessary to evaluate what is the cost and the consequences of changing the plans based on a forecast for the taking of decisions.

Since the phases of ENSO repeat with erratic periods and that the forecast tendency are not perfect, the general value of the forecast will arise of evaluating long-term economic consequences of adopting a forecast for the taking of decisions.

3.8 Conclusions

- In most of the Pampa region during El Niño events, a high probability exists of having above-normal precipitation during the months of November, December and January. On the contrary, during La Niña events, a high probability exists of having below-normal precipitation in October, November and December of the year that the event begins, and in March and April of the following year.
- The influence of La Niña on the precipitation of the Pampa region is more intense and more persistent than that of El Niño.
- Corn is the most sensitive crop and there exists a high probability of obtaining above-normal yields during El Niño events and below normal yields during La Niña events.
- For soybeans, the biggest impact on yield is during La Niña events, with high probability of having below-normal yields in the main production area (northern Buenos Aires, southern Santa Fé and Córdoba), while during El Niño events yield increases would only occur in some isolated areas.
- For wheat, above-normal yields can be expected during El Niño events and below-normal in La Niña events in the south-southwestern area of Buenos Aires and La Pampa. Management practices that could influence the national production sensibly for the great area sowed in this region??.
- Sunflowers demonstrated a contrary behavior, with a high probability of having below-normal yields during El Niño events in a large part of Buenos Aires. On the contrary, the possibility of having above-normal yields during La Niña events is restricted to isolated areas.
- For corn, soybeans, and wheat the increments of yield reductions according to the ENSO phase is directly associated with increases or decreases of precipitation.
- For sunflower, yield reductions during El Niño events is associated with excess precipitation in January and February in the western areas, and during December in the central area of the production.
- The area abandoned increases during La Niña events for corn in most of the Pampa region.
- For the national production of cereals and oilseeds, the benefits of El Niño events would be smaller than the losses during La Niña events.

CHAPTER 4

LONG-RANGE FORECAST PROGRAM IN SOUTH AMERICA

Mr G. Hugo
Dirección Meteorológica de Chile
Aeropuerto Arturo Merino Benitez, Casilla 63
Santiago, Chile
ghugo@meteochile.cl or ghugo@meteorologos.cl

4.1 Introduction

Humanity is very vulnerable to the impacts of climatic variability in the agricultural sector, especially in those regions prone to disasters. One of the main sources of the interannual climatic variability is the El Niño-Southern Oscillation (ENSO) phenomenon that refers to changes in the sea surface temperature (SST) in the area east of the Equatorial Pacific ("El Niño" in warm years, "La Niña" cold years) and the associated changes in the gradients of atmospheric pressure and to wind patterns in the tropical Pacific.

The National Meteorological Services in South America are developing seasonal forecasts and climate prediction in operational agriculture using anomalous SST changes in the gradients of atmospheric pressure and to wind patterns in the tropical Pacific and the variability of deep atmospheric convection over the central and eastern Pacific Ocean, the continent of South America.

4.2 El Niño-Southern Oscillation

4.2.1 El Niño

The term "El Niño" was used originally by the Peruvian fishermen to refer to a weak warm oceanic current that runs toward the south along the coasts of Peru that it was called the current of the El Niño that appears at the end of year, near Christmas time. The term was later associated with above-normal SST anomalies that occur once every 2 to 7 years, altering the local and regional ecology (Trenberth, 1996). These above-normal SST anomalies occurred in the equatorial Pacific up to the Date Line (180º of longitude) and they can initiate atmospheric perturbations that can alter the global climatic patterns in both hemispheres, by means of processes that are called "atmospheric teleconnections".

The atmospheric component that is associated to the "El Niño" cycle corresponds to the Southern Oscillation Index (SOI) that was first studied during the end of the 19th Century. Scientists define the SOI as the fluctuation of the sea level pressure between the equatorial Pacific and the region of Indonesia-Australia. The largest changes in the pressure happen in intertropical latitudes of the southern hemisphere. Scientist determined that the key points to measure these fluctuations of the atmospheric pressure are the stations of Tahíti and Darwin (north of Australia). By means of the values of monthly pressure, measured by both stations, the SOI is defined as the difference of pressure between Tahíti and Darwin, expressed in standard deviations. When the index reaches a negative value, it is related with warmer SSTs, typical of the El Niño phenomenon. If the SOI is positive and it persists for several months, it is associated to the phase of La Niña, or colder SSTs.

In the 1960s, the scientists established a relationship between the values of the atmospheric pressure (SOI) and the sea-surface temperatures in the equatorial Pacific and defined these processes of ocean-atmosphere interaction as the El Niño-Southern Oscillation (ENSO).

The simplest way of representing the typical atmospheric circulation in the equatorial Pacific is by means of the Walker circulation pattern defined by Bjerknes (1969). This model is defined by the longitudinal thermal contrast among the area of relatively cold waters of the eastern Pacific (22ºC) and the warmest waters in the region of Indonesia-Australia (29ºC) and it comprises of the following basic components:

- Easterly surface wind flow or winds that blow from the South American coast toward Indonesia-Australia, corresponding to the trade winds, convergence and ascent of the masses of warm and humid air that generates abundant convective cloud and precipitation in the sector of the western Pacific, between the north of Australia and the Asian southeast.

- Westerly wind flow in the high troposphere, the descent of air (subsidence) in the oceanic part, in front of the costs of South America (Chile and Peru) that maintain a very stationary area of pressure known as the subtropical anticyclone of the South Pacific.

With these atmospheric characteristics, there is associated accumulation of warm water near Indonesia and an upwelling of colder subsurface water along the coast of Peru, Ecuador and northern Chile. The trade winds also produce a balance of water toward the sector of the western Pacific generating a slight inclination of the sea level on the order of 60 centimeters.

The main features that characterize to the climatic phenomenon “El Niño” include: the weakness of the easterly trade winds and of the subtropical anticyclone of the South Pacific; the displacement of warm waters eastward toward the South American coast; decreased ocean upwelling; the increase of the sea level (20 to 30 centimeters) along the coast of South America; the eastward displacement of the area of maximum convection, precipitation and sustained heating from 12 to 18 months of the SST in the equatorial Pacific.

4.2.2 La Niña

The term “La Niña”, describes the group of oceanic and atmospheric anomalies that occur in the equatorial Pacific, generally when the El Niño phenomenon ends. The location of the oceanic and atmospheric system is similar to normal situation, and the main characteristics defines SSTs of 1° to 3ºC below-average, for a period of several months and covering an extensive area, between the coasts of South America and Indonesia-Australia. Other terms used to refer to this same phenomenon, but less frequent in the scientific literature they define “Anti-El Niño”.

4.3 Atmospheric Aspects and Atmospheric Teleconnections

4.3.1 Mechanisms of remote influence of the atmospheric circulation

There are mechanisms that can influence the atmospheric circulation that relates to the anomalous warming of the central equatorial Pacific with the increase of the precipitation in Chile (Rutllant, 1997). This theory of atmospheric teleconnection (Karoliy 1989) states that due to the warming of the sea surface in the central Pacific during “El Niño”, large tropospheric anomalies can develop in the atmospheric circulation. That is to say, areas of positive and negative anomalies of height quasi-stationary geopotential can produce a wave-train pattern from the equator toward higher latitudes, with the negative anomalies (lower pressure) located near central Chile and the positive anomalies (higher pressure) located at the southern portion of the South American continent. Such an atmospheric condition is favorable to the development of frontal systems during the autumn-winter (April-September) period and increases precipitation in central and northern Chile. Conversely, in the southern region of Chile, due to the prevalence of the anticyclonic conditions and of atmospheric blocks, below-normal precipitation can occur.

4.3.2 Jet streams

Another atmospheric elements that present variable characteristics during different stages of the ENSO phenomenon is the jet stream, which is defined as winds of 120 km/hr located between 10 and 15 kilometers of height. The jet stream typically found at a latitude of 30º is called the subtropical jet and the one located at a latitude of 60º is called the polar jet. These jets are located above the Pacific region in both hemispheres. During "El Niño" episodes, the strong thermal contrast between the equator and the high latitudes produces an increase of the western flow in the medium and high troposphere and the subtropical jet during the winter and spring periods. Also observed is the weakness of the polar jet located in the subpolar latitudes (Chen B. and other, 1996). Such conditions began to be observed in the Southern Hemisphere starting from June 1997 until April 1998. This atmospheric pattern established a greater activity of storms and front systems that produced above-normal precipitation for northern and central Chile during 1997 (NOAA, 1997; WMO, 1998).

4.4 El Niño and La Niña in Various Regions of South America

4.4.1 Argentina

In central Argentina the signs of the "El Niño" are manifested with an increase of winter temperatures and a significant increase of precipitation during the months of November - February. On the contrary, during the "La Niña" event, negative anomalies of winter temperatures and values of below-normal precipitation are observed in the months of June to December.

4.4.2 Chile

The interannual variability of precipitation in central Chile is associated in great measure to ENSO, where most of the years the annual precipitation is within a standard deviation from the average, a feature that defines the rainy year, is present to warm or "El Niño" event. Similarly, most of the years in which the annual precipitation in central Chile is a standard deviation less than the average, coincides with a cold or La Niña event (Rutllant, 1997).

A negative SOI phase (larger atmospheric pressure of Darwin that in Tahíti) is associated with warm episodes of "El Niño" and is related with abnormally abundant precipitation during the winter season in central Chile (Aceituno, 1987).

The increase of frontal activity during the winter season in central Chile and the northern deviation of the trajectories is associated mainly to the presence of the subtropical jet of the relatively weak south Pacific high pressure and the occurrence of atmospheric blocks in the southern portion of the continent (Rutllant and Fuenzalida, 1991).

A statistical relationship was carried out between the precipitation of central Chile during April to September and the phenomena "El Niño", "La Niña" and the Southern Oscillation Index. The method of simple linear correlation was applied to the precipitation of Santiago, Chile, which was selected to best represent climatic phenomena in central Chile.

The dependent variable (Y-axis) corresponds to the precipitation totaled between April and September for the period 1950-1998. This seasonal period was considered since it represents the precipitation that accumulates during those six months in the central area and it accounts for 70% of total yearly rainfall.

One of the selected independent variables (X-axis) was the SST anomalies corresponding to the area of monitored denominated "El Niño 3". This oceanic area of the equatorial Pacific (5ºN-5ºS, 150ºO-90ºO) appears their biggest effects in the atmospheric mechanisms of our country. The second independent variable was the SOI. In both variables the arithmetic average of the anomalies was used between the months of April and September.

The obtained results, represent the statistical relationship between the precipitation of central Chile and the SST anomalies in the equatorial Pacific, Santiago is the place that best responds to the variations of the precipitation during “EL Niño” and “La Niña” conditions. The correlation obtained for Santiago was +0.64 (64%), what means that a significant direct relationship exists among the quantity of registered precipitation between April and September of one year with the anomalies of the SST of the equatorial Pacific. In the rest of the climate stations processed, although the relationship is statistically significant, the correlation was smaller.

The linear correlation calculated between the precipitation central Chile and the SOI was inversely proportional (negative linear correlation) and the result indicated that Santiago again obtained the largest correlation of –0.64. That is to say, a statistically significant inverse correlation exists among the quantity of precipitation in central Chile and the difference of atmospheric pressure between Tahiti and Darwin, corresponding to the SOI.

Station	Precipitation vs SST	Precipitation vs SOI
La Serena	0.54	-0.41
Santiago	0.64	-0.64
Curicó	0.42	-0.51
Concepción	0.31	-0.38

The simple linear correlation was undertaken among the quantity of seasonal precipitation (autumn and winter) of Santiago and the SOI anomalies with regard to the SST anomalies of the “El Niño 3” area. The analyzed period covered the years between 1950 and 1998.

A strong dependence exists among the increase (decrease) of precipitation during the months of April to September in central Chile (30º at 40º) and the warming (cooling) of the SSTs in the “El Niño 3” area. In other words, a 65% probability exists that above-normal rainfall will occur in the presence of “El Niño” and below-rainfall deficits in the presence of “La Niña”.

4.4.3 Precipitation anomalies in central and southern Chile during the 1997 El Niño and 1998 La Niña

The main characteristic of the atmospheric circulation that dominated the Southern Hemisphere, especially in the southeastern Pacific during the first months of 1997, was the prevalence of an intense anticyclonic circulation in the middle troposphere (500 hPa) and at the surface that affected central and southern Chile and Argentina. Preceding the 1997 El Nino event, there was a La Niña during 1995 and 1996 and this was pre-existing atmospheric condition during the season of the southern summer of 1997.

The return to normal SST from the cold conditions at the beginning of 1997 and the later anomalous heating of the SSTs in the central and eastern equatorial Pacific during the months of March-April generated in the later months (May-August) the typical patterns of atmospheric circulation of the warm phase of the ENSO. In other words, the weakness of the subtropical anticyclone in the south Pacific, represented by negative sea level pressure anomalies along the Chilean coast and the blocking high pressure in the high latitudes of the eastern Pacific, initiated the development and increased the frequency of frontal systems in central and northern of Chile (26ºS at 43ºS).

This synoptic configuration caused precipitation episodes that exceeded historical values. During June and August 1997, extreme precipitation events occurred which contributed to Santiago's accumulated 1997 annual precipitation of 712.9 millimeters, which was the fourth wettest year during the 20th Century.

In the spring of 1997 and summer of 1998, the synoptic configurations were characterized by the development of a smaller frequency of frontal bands and negative anomalies of the surface pressure and at 500 hPa across central and northern Chile.

According to the analyses, the significant anomalous conditions of the atmospheric circulation associated to the 1997 El Niño event started in May 1997. The lingering weaken of the subtropical anticyclone of the south Pacific, caused negative anomalies of the atmospheric pressure between –1 and –4 hPa, centered on the months of May to September 1997 and between December and January 1998. The air temperature on average, showed positive anomalies between 2º and 3ºC, with two relative maximums during July-August 1997 and December-January 1998. The precipitation during 1997 was significantly increased and was above-normal especially in northern and central Chile.

Starting from April of 1998, the atmospheric conditions were opposite of the previous year in relation to the winter rains, especially with an extremely dry September. The lack of precipitation in Chile during the winter period of 1998 was associated with the synoptic configurations characterized by the persistence of the abnormally intense subtropical Pacific anticyclone that extended more southward than usual.

The change of the SSTs in the equatorial Pacific from very warm in the first months of 1998 (January-April) associated to “El Niño”, to cold conditions of “La Niña” (starting from the second semester of 1998), altered the patterns of atmospheric circulation at the global level. In Chile, the most prominent characteristic was almost permanent presence of the subtropical jet at the latitudes of 40º to 45º S during the months of May and July 1998 that reduced precipitation during the rainy season in central Chile in 1998 and 1999. During 1998, the annual precipitation of Santiago was 89.7 millimeters, the third driest year in the last 100 years.

The atmospheric blocking observed during most of the period between May 1998 and July 1999 impeded the normal placement and development of frontal systems in central and northern Chile and caused a latitudinal extension of the systems between the 35º and the 45ºS. The water deficit in 1998, varied between 70% and 80% regarding to normal for the area between 30º and 36º S. Between 37º to 45º S, the recorded rainfall reached a deficit between 30% and 50%. Only the southern region (Punta Arenas) was received somewhat normal rainfall.

During the first half of 1999, the meteorological conditions in Chile were similar to those observed in the previous year, with rainfall deficits across almost the whole country, but of smaller magnitude to the one observed in 1998. Central Chile was the region with the biggest rainfall deficit up until July 1999 with values varying from 40 to 80% lower than average.

4.4.4 The South American Highland

The South American Highland, with a near elevation to the 4000 m and a latitudinal extension of 600 Km, includes the areas of Bolivia, Peru and Chile. These highlands have notable impact on the atmospheric circulation in the tropical and subtropical region of South America during the summer. The Amazon Basin is to the northeast of this region, where humid and warm conditions prevail. In relation to the interanual variability of precipitation in the Highland, a smaller accumulation of snow during the El Niño events has been observed. During La Niña events, an abnormal rainy cycle has been observed across the Highland.

4.4.5 Paraguay, Southern Brazil and Uruguay

The region covering Paraguay, southern Brazil and Uruguay often receives more rainfall than normal in winter and spring during El Niño events and observes a displacement of storm activity over northeastern Brazil.

4.4.6 Colombia

Rainfall over northern Colombia is much below-average during summer (December, January) with El Niño events. However, as the inter-tropical convergence zone begins to retreat northward during its annual cycle, much above average rainfall occurs in February.

4.5 The Seasonal Climate Forecast in South America

The seasonal climate forecast in South America is valid for the following three months and takes in account the forecasts of SST anomalies from NOAA, experimental climatic models of temperature and precipitation from the UK Met Office and IRI, historical analysis of the time series of meteorological stations (national atmospheric index) and current situation of the dominant atmospheric circulation patterns . Currently in Colombia, seasonal forecasts are issued every 1, 3, and 6 months in advance based on a statistical model of autocorrelation and on a model developed at the Instituto de Hidrología, Meteorología y estudios Ambientales (IDEAM) based on the analysis of intra-seasonal waves, climatic variability and climatological tendency.

The forecasts are only qualitative and indicate only the features of the expected below/above normal precipitation and temperature. At the present, the National Meteorological Service's do not have any operational climate models that use the above mentioned elements for making seasonal forecast. No methods are currently in use for assessing the results of the forecasts.

Currently, seasonal forecasts and climate predictions are used in the planning of sowing operations, irrigation scheduling and in economic decisions by farmers when critical meteorological events occur in the neighbouring countries.

The forecasts are made every month and are delivered to the Ministry of Agriculture and to general public through Monthly Agricultural Bulletins, the web site of the National Meteorological Services and through agricultural newspapers ten days in advance.

Brazil had implemented INMET - Bulletin Board System whose purpose id to distribute meteorological and agrometeorological products, satellite images, forecasts, and early warnings. This system works using software and a fax-modem. It has 15,000 direct users, reaching 100,000 indirect users through an agreement signed mainly with the National Confederation of Agriculture that distributes the meteorological products to the 4000 organizations of peasants, looking at their application and profit in the agriculture.

4.6 Early Warning

The regional study of the El Niño Phenomenon (ERFEN) Program of the southeast Pacific is a multidisciplinary program in the meteorological, oceanographical, biological, fishing, training and socio-economic fields. ERFEN's fundamental goal is predicting oceanic-atmospheric changes with enough advance warning to allow for the establishment adaptation and emergency (Early Warning) actions in relation to variations of fishing, agricultural and industrial outputs. It also can provide marketing decisions and the handling of hydrobiological resources. ERFEN is comprised by the member countries (Colombia, Ecuador, Peru and Chile), 17 scientific institutions and the Permanent Commission for the South Pacific (CPPS), which is acting as Organism International coordinator of the program. The current headquarters of ERFEN is in Ecuador.

4.7 References

Aceituno P. 1987. On the functioning of the Southern Oscillation in the South America Sector. Part I: Surface Climate. Monthly Weather Review, Vol. 116 Nº3, p.505-523.

Bjerknes J. 1969. Atmospheric teleconnections from the equatorial Pacific. Monthly Weather Review. 97, p 163-172.

Bulletins of the NOAA. 1997. Climate Diagnostics Bulletin, Climate Prediction Center Nº6 at the 12.

Chen B., S. Smith, and D. Bromwich D. 1996. Evolution of the Tropospheric Split-up-up Jet over the South Pacific Ocean during the 1986-1989 Enso Cycle. Monthly Weather Review, Vol 124, Nº 8, p 1711-1731.

Karoly D. 1989. Southern Hemispheric Circulation Features Associated with “El Niño”-Southern Oscillation Events, Journal of Climate, Vol 2, p 1239-1252.

World Meteorological Organization. 1998. The “El Niño” Update Bulletin. Nº 5

Rasmusson E.M. and T.H. Carpenter. 1982. Variations in tropic is surface temperature and surface wind fields associated with the Southern Oscillation/El Niño. Monthly Weather Review, 110, p 354-384.

Rutllant J. 1997. Anomalies pluviométricas in central Chile. Report Technical Intersector Committee for the Phenomenon “EL Niño”, scientific Subcommittee, Chile.

Rutllant, J. and H. Fuenzalida. 1991. Synoptic aspects of the central Chile rainfall variability associated with the Southern Oscillation. *Int. J. Climatol.,* 11**,** 63–76..

Trenberth, K.E. 1996. On the definition of EL Niño, Clivar Exchanges Newsletter Vol. 1, Nº 3, 6.

CHAPTER 5

USE AND DISSEMINATION OF SEASONAL CLIMATE FOREASTS IN AGRICULTURAL PRODUCTION IN AFRICA

I. Tarakidzwa
Zimbabwe National Meteorological Services
P.O Box BE 150, Belvedere
Harare, Zimbabwe

5.1 Abstract

The annual variation on the onset, intensity, duration and cessation of the rainfall has negative impacts on socio-economic, agricultural and environmental development. Hence the need for seasonal climate forecasting information, which seeks to minimize the risks and hazards, associated with annual climate variations. Seasonal forecast information has been found, in agriculture, to be a useful tool in decision making particularly in selection of appropriate crop cultivars and varieties, input acquisition and levels, timing of agricultural operations and implementation of proper livestock and crop management strategies. However, socio-economic conditions in most African countries tend to suppress maximum usage of seasonal forecasts because farmers particularly in remote rural areas do not have access to resources such as labour, draft power and credits. The majority of the rural farmers do not have access to the standard media channels such as radios, newspapers, televisions, Internet, e-mail and so on. By the time the forecasts get to them they would have already made their decisions based on traditional forecasting knowledge. However the use of the RANET system (**RA**dio and Inter**NET)** project, which has been successfully implemented in Niger, would go a long way in the outreach of remote rural areas. The project's objective is to break the isolation of rural African communities and to use rural community radio programmes to involve them in meteorological data observation and use.

Several studies on the use and dissemination of seasonal forecasting information have been carried out in various parts of Africa. Hence, this paper seeks to review these studies and outline their main findings. The paper also reviews the current advances in seasonal forecasting and climate prediction and the products and services relevant to agriculture, the current applications and possible impacts of seasonal forecasts, and recommend ways to use and disseminate optimally the seasonal forecasts and climate prediction in operational agriculture.

5.2 Introduction

The impacts of climate variability on agriculture are large, particularly in Africa where agricultural production is the mainstay of the economy. Significant world-wide progress has been made in the last decade regarding generation of seasonal climate forecasts but applications of forecasts are still not yet well developed and it remains unclear what limitations may hamper the adoption of forecast information in decision-making processes, both at local and national levels (Unganai et al. 2001). Reliable forecast information acts as a useful tool in decision-making, particularly in selection of appropriate crop cultivars and varieties, input acquisition and levels, timing of agricultural operations and implementation of proper livestock and crop management strategies.

Although seasonal climate forecasts have been issued for many years, the benefits for agricultural production appear to be difficult to quantify with respect to increased and/or sustainable production. However, field studies carried out in many countries in Africa suggest that the gap between information requirements of farmers and that provided by climate experts is narrowing through constant interactions. The Regional Climate Outlook Forums; SARCOF for Southern Africa, PRESSAO for West Africa and GARCOF for the Greater Horn of Africa have provided a platform for user –producer feedbacks. These have increased the use of seasonal climate forecasts as more and more people become aware of their existence, usefulness and limitations. Studies carried out in many countries to investigate the use of seasonal climate forecasts in operational agriculture, has shown an increase in the appreciation of meteorology as a component of agriculture amongst farmers as evidenced by their change of attitude. However, problems of effective dissemination and communication exist in many rural areas of Africa.

The majority of the rural farmers do not have access to the standard media channels such as radios, newspapers, televisions, Internet, e-mail and so on. By the time the forecasts get to them they would have already made their decisions based on traditional forecasting knowledge. However the use of the RANET system (**RA**dio and Inter**NET)** project, which has been successfully implemented in Niger, would go a long way in the outreach of remote rural areas. The project's objective is to break the isolation of rural African communities and to use rural community radio programmes to involve them in meteorological data observation and use.

Another impediment is the lack of local specificity in the seasonal forecast. Farmers require area specific forecasts in order to come up with management strategies appropriate for their areas. Several studies have been carried out in various countries on the use and dissemination of seasonal forecasting information. Hence, this paper seeks to review the various studies that have been carried out in various parts of Africa and outline their main findings. The paper also reviews the current advances in seasonal forecasting and climate prediction and the products and services relevant to agriculture, the current applications and possible impacts of seasonal forecasts, and recommend ways to use and disseminate optimally the seasonal forecasts and climate prediction in operational agriculture.

5.3 Terms of Reference (a): In liaison with the CLIPS project, review and summarize the current advances in seasonal forecasts and climate prediction and the products and services relevant to agriculture that are becoming available based on these forecasts

Seasonal rainfall forecasting over Africa remains an important piece of the puzzle that needs to be untangled within the vagaries of weather and climate variability. This is due to the region's dependence on rainfed agriculture. There are few National Meteorological Services in Africa that has the capacity to run advanced climate prediction models and generate forecasts independently. Most of them rely on products from other advanced climate centers both within and outside the region, and on products derived from the Drought Monitoring Centers. The Drought Monitoring Centers were established due to frequent severe episodes of droughts in the 1980s. Sub-regional organizations and the United Nations held several discussions on the frequent occurrence of drought in Africa and this resulted in the establishment of two Drought Monitoring Centers (DMC), one in Nairobi, Kenya and the other in Harare, Zimbabwe. The main mandate of the two centers is to produce and disseminate regular and timely seasonal climate outlooks and advisories on drought including the onset and cessation and its severity and extent.

The Drought Monitoring Centers use mainly statistical approaches in generating seasonal climate outlooks. These can be summarized as follows (Unganai 1998):

5.3.1 Regression

These are basically empirically derived linear associations between the predictand (rainfall) and predictors. The main problem with this approach is that it is like a black box; it does not explain why a relationship exists between two variables. Extremes are not handled well by regression models. It is also unfortunate that regression models give a deterministic answer instead of a probabilistic one. However, instead of using the point estimate, the 95% confidence band is used to classify the forecast rainfall category.

5.3.2 Analogue

This approach is based on the assumption that the previous states of the atmosphere can provide potential insight into future ones. The evolution characteristics of the predictand(s) and predictor(s) are first determined to which a close analogue is sorted from historical cases. This technique is quite useful if large-scale features are used. Currently, wind circulation anomalies, SOI trend, and SST anomaly fields are interpreted using the analogue approach. The only weakness with this approach is that weather patterns sometimes do not exactly occur again. Thus the approach gives only approximate outlooks, just like any other forecasting technique.

5.3.3 Period analysis

This technique seeks to extract principal periods from the predictands' series followed by their extrapolation into the future. This approach was once popular following the identification of quasi-cyclicity of about 17 – 18 years in the region's rainfall series. The problem with this approach is that it is blind to the factors that generate those cycles, which should be the key factor. It has since been noted that the country's rainfall cycles are largely an expression of the ENSO signature.

5.3.4 Integration of indigenous knowledge in seasonal climate forecast

Although National Meteorological Services in Africa do not use local traditional seasonal climate indicators in generating seasonal climate outlooks, they are fully aware of the existence of such practices in many countries. Several studies have been carried out to investigate the use of contemporary and indigenous climate forecasts information for farm level decision making in several countries such as Zimbabwe (Shumba 1999), Mozambique (Lucio 1999), Namibia (Hochobeb 2001) and Tanzania (Kihupi et al. 2000). The studies found a lot of similarities in the type of traditional indicators used in these countries. The report submitted to the Drought Monitoring Center in Harare (Kihupi et al. 2000) gave examples of some of the traditional indicators currently being used in various countries. These are:

- Certain tree species are observed dripping water from their leaves. Species of *Ormocarpum trichocarpum* and some *Combretum spp*. are used as indicators by rural people in Zimbabwe. Water dripping from these trees around September/October can indicate a good rainy season. However, in Tanzania, water dripping from the *Albizia* scimperiana tree indicates the same thing.

- The appearance of ants in great numbers signals above normal rains in Zimbabwe, Namibia, Mozambique and Tanzania (Kihupi et al. 2000). In Tanzania and Zimbabwe, however, the occurrence of armyworms can indicate drought.

- In both Zimbabwe and Tanzania rumbling sounds heard from sacred mountains in October, indicates good rains.

- The birth of many baby girls compared to boys prior to the rainy season signals good rains. A number of people recall such statistics in Dodoma region in Tanzania prior to the 1997/98 seasons, which was an El Nino year.

- A higher than normal flowering density of certain trees. Mangoes (*Mangifera indica*) are used as indicators to predict good rains if they bear many flowers both in Zimbabwe and Tanzania.

The use of traditional indicators in many African countries indicates the degree of acceptance of the forecasting schemes, which have been there for generations. With growing affluence and access to modern communication channels, rural farmers are exposed to more scientifically based forecasting information (Kihupi et al. 2000). However as has been noted in Zimbabwe (Shumba 1999), the majority of the poor and marginalized farmers use their traditional knowledge systems of climate forecasting as controls. The more contemporary climate forecasting information deviates from the control, the less the farmer uses this for planning purposes.

It is also worth noting that a number of the commonly used traditional weather indicators can be explained meteorologically. For example the flowering of certain trees is in response to the temperature regime (or heat build-up), and the behaviour of some ants could be a response to the pressure field, whereas, migratory birds follow wind movement.

5.3.5 Characteristics of current seasonal forecasts

The current seasonal climate forecasts are being expressed in tercile probabilities that indicate the chance of rainfall expected in the following categories: above-normal, normal, and below-normal. The higher the probability, the more likely the event will occur. Hence users are encouraged to make weighted decision biased towards the category with the highest probability.

These probabilities are derived from historical data for a 30-year period. Over the 30-year period, the data is ranked from the highest value to the lowest and then divided into 3 groups called terciles. The top 1/3 indicates the above-normal years (top number), the middle 1/3 indicates the near-normal years (middle number), and the bottom 1/3 indicates the below-normal years (bottom number). The probabilities developed using statistical models indicate the chances of the expected rainfall or temperature falling within each of the three terciles. The probabilities indicate the percentage chance of above-normal, normal and below-normal rainfall or temperature in each category; but do not indicate the exact amount of rainfall in millimeters or temperature value.

These forecasts have certain general characteristics, which must be borne in mind when using them. Thus the seasonal forecasts (Unganai, 1998) are:

a) Areal average: This constraint is imposed by lack of data, and the complexity of the climate system.

b) Time averages: The seasonal forecast usually covers periods ranging from 3 to 6 calendar months and information on intra-seasonal variability cannot be extracted from the current seasonal forecasts.

c) Based on a limited number of known predictors: This affects the accuracy of the forecasts from year to year.

d) Skilful from about July onwards: Predictors have to show some stability before they can be used in the forecast. This stability can be assessed from about July onwards. This constraint limits the timing of the seasonal forecast.

e) Probabilistic in character: The atmosphere is not perfectly predictable because of the non-linearity of the various processes in the system. Furthermore, the atmosphere is never completely observed to allow for perfect initial conditions for running the models. To reflect this inherent uncertainty, seasonal forecasts are best developed in a probabilistic setting.

5.3.6 Dissemination and communication of seasonal climate forecast

Before the start of season, the Drought Monitoring centres organize regional seasonal outlook forums (SARCOF for Southern Africa, PRESSAO for West Africa and GARCOF for the greater Horn of Africa). These forums bring together climate experts from both within and outside the region in order to come up with a consensus forecast for the coming season.

The drought Monitoring Centres have also been organizing pre-SARCOF and pre-GARCOF Capacity Building workshops for a number of years. The main objective of the pre-season workshops is to enhance the capacity of the National Meteorological Services (NMSs) in Africa to generate climate outlook products at their own institutions and to ensure maximum application of climate information and prediction services in sustainable socio-economic development of the countries in the region.

Once the consensus forecast has been reached, the Drought Monitoring Centres disseminate the forecast as both hard and electronic copies to all NMSs and participants present at the outlook forums The NMSs take this product and downscale it and issue national seasonal forecasts for their respective countries. A survey carried out indicate that most of the countries disseminate their products through the standard media channels such as radios, newspapers, televisions, Internet, e-mail and so on.

Surveys carried in South Africa (Walker et al. 2001), in Zimbabwe (Unganai et al. 2001) and in Zambia (Nanja, 2001) ranked the radio as the most frequent used source of seasonal forecasts. The seasonal forecast information is translated from English into local languages and aired on the radio so that the beneficiaries are able to understand the message and take appropriate measures. The findings of the surveys mentioned above indicate that appropriate media and channels of communication to provide seasonal forecast information to commercial and small scale farmers are already well established. However, it has been sadly noted that the majority of the rural farmers do not have access to these standard media channels.

Most rural farmers do not have access to radios, newspapers, televisions, Internet, e-mail and so on. By the time the forecasts get to them they would have already made their decisions based on traditional forecasting schemes (Phillips et al. 2001). The only effective dissemination option is communication of the forecasts through the extension staff, which is labour intensive and requires a lot of resources for the extension staff to travel from one point to the next meeting the farmers. It would be useful to implement the RANET system (**RA**dio and Inter**NET)** project, which has been successfully implemented in Niger. The project's objective is to break the isolation of rural African communities and to use rural community radio programmes to involve them in meteorological data observation and use.

The studies carried out in South Africa, Zimbabwe, Namibia, and Zambia indicate an increased appreciation of meteorology as a component of agriculture amongst farmers. The studies also imply that application of meteorology in agriculture for farmers is directly dependent on their understanding of it. However, problems of effective dissemination and communication exist in many rural areas of Africa. For example, studies carried out in South Africa (Walker, et al. 2001) identified some problems of communication between meteorological services and farmers. Scientists use technical terms that are beyond the understanding of ordinary farmers. This hinders the maximum use of climate information in operational agriculture even though the media and channels of communication of meteorological information are well established.

Scientists involved in the dissemination of information for farming purposes, should understand the target audiences and their specific needs. The use of technical terms makes the target audience excluded secluded. Not many rural people understand probabilistic forecasts. Hence information targeted for the rural population should be prepared in their local languages and packaged in such a way that they would understand.

5.4 Terms of Reference (b): To survey and summarize, using appropriate case studies, the current applications and possible impacts of seasonal forecasts and climate prediction in agriculture, forestry and livestock management

Seasonal climate information is vital for planning and decision making in operational agriculture. It seeks to minimize the risks and hazards, associated with annual climate variation. It is a useful tool in selection of appropriate crop cultivars and varieties, input acquisition and levels, timing of agricultural operations and implementation of proper livestock and crop management strategies. Although seasonal climate forecasts have been issued for many years, the benefits on agriculture production appear to be difficult to quantify with respect to increased and/or sustainable production. However, field studies carried out in many countries in Africa suggest that the gap between information requirements of farmers and that provided by climate experts is narrowing through constant interactions. The Regional Climate Outlook Forums (SARCOF for Southern Africa, PRESAO for West Africa and GARCOF for the greater horn of Africa have provided a platform for user–producer feedbacks. This has increased the use of seasonal climate forecasts as more and more people become aware of their existence, usefulness and limitations.

5.4.1 Current applications and possible impacts of seasonal forecasts: Zambia's perspective

The studies carried out in Zambia (Nanja, 2001), attempted to investigate the extent at which meteorological information was being used in rural areas in Zambia. A provincial early warning system was set up in the Southern province. Its purpose was to provide as much meteorological information as possible to farmers, provincial and national planners and the general public for effective planning.

Farmers were provided with radios, batteries and audiocassette tapes. This community empowerment enabled them to access to the broadcasted meteorological information from radio stations. The cassette recording facility accorded them an opportunity to replay any programmes at their convenient time. This provided each farmer an opportunity to get the right information.

Several stakeholders' workshops and meetings were held. The person-to-person discussions in exchanging meteorological information enabled the farmers to ask questions on other relevant issues.

Meteorological radio programmes were broadcasted in local languages. Radio drama programs were also aired. Radio programs were run successfully and were very popular amongst the community. The meteorological information passed through the radio drama and done in community's local language was easily understood and appreciated by the farmers. It's an effective way of disseminating information. The most effective method of disseminating information was that of using drama sketches in the community centres.

Music also plays a major role in disseminating information. The meteorological song, which was composed and used as a tune for all radio programs, relayed the meteorological message in its own way. The involvement of the local leadership in this study assured continuity and sustainability.

The results from this study indicated that:

- Accessibility to meteorological information could also greatly help in the improvement of agricultural productivity. The percentage farmer understanding of meteorology has increased considerably of late and this should contribute to increased agricultural productivity. Thus meteorology must be explained in a friendly manner to the community if it has to be accepted as a factor of their livelihood.

- Farmers do not only need increased meteorological information but that it has to be disseminated in a user-friendly manner. It helps to reduce the time one has to help farmers understand the importance of meteorological information in agriculture.

5.4.2 Current applications and possible impacts of seasonal forecasts: Zimbabwe's perspective

Upon receiving a seasonal climate forecast, communal farmers usually approach agricultural extension staff for technical advice since most of them reside in marginal areas, which are highly exposed to climatic risk. For them to capture the benefits of climate forecast information, they need the advice from extension staff. Their role is to ensure that the farmer has received the forecast, assist the farmer to understand the forecast and guide the farmer in making appropriate farm management strategies.

When formulating the extension messages, extension personnel in collaboration with agrometeorologists should always consider:

- Past rainfall patterns in the farmer's area, that is the amount and distribution, start and end of season.

- Typical agricultural management practices in the area. By examining historical records of similar situations to the current one, the likely outcomes of different management options can be determined.

- The prevailing socio-economic climate that is prices, markets, household resources, etc.

- Farm management options familiar to the area in order to avoid resistance.

- The seasonal rainfall forecasts and the associated probabilities

A sample survey on the use of seasonal forecasting information in Zimbabwe (Unganai et al. 2001) confirms that farmers now appreciate the importance of climate information in planning agricultural activities. The diagram below (Fig. 5.1) summarises farmer's responses in percentages per natural region for the survey. Farmers clearly pointed out the need for seasonal forecasts in order to decide on the planting dates as well as selection of crop cultivars and varieties.

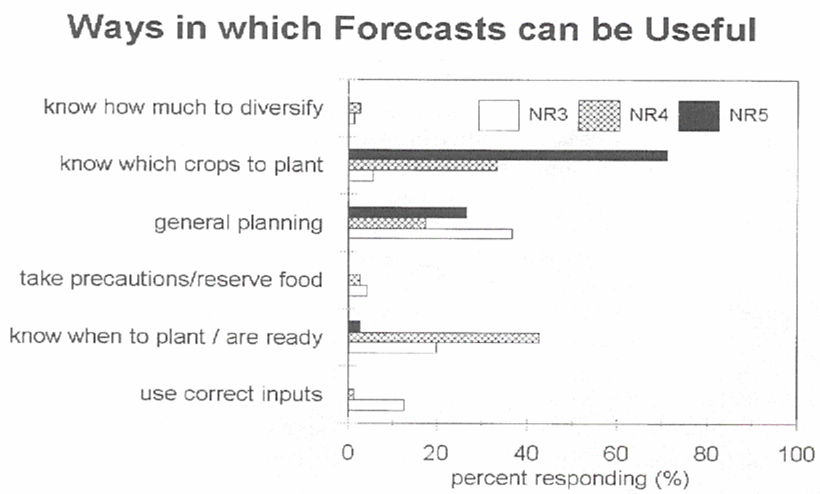

Figure 5.1 Climate information cited as most useful in farm management decisions in advance of the rainy season (Source: Phillips et al. 2001).

Farmers know that not all rainfall is available for crop use. Rainfall may be lost through runoff (depending on slope of soil surface), evaporation (from soil surface), deep percolation and subsurface flow. Farmers and extension workers should plant the recommended varieties for their areas in order to obtain the best yields. Information on the onset and cessation of rains is critical in decision-making as to when to plant and what variety and therefore, farmers and extension staff should always consult the agrometeorologists in their respective NMS for information regarding mean planting dates of their respective areas. Figure 5.2 summarises by natural region, seasonal forecast information, which have been found to be very useful by communal farmers in Zimbabwe.

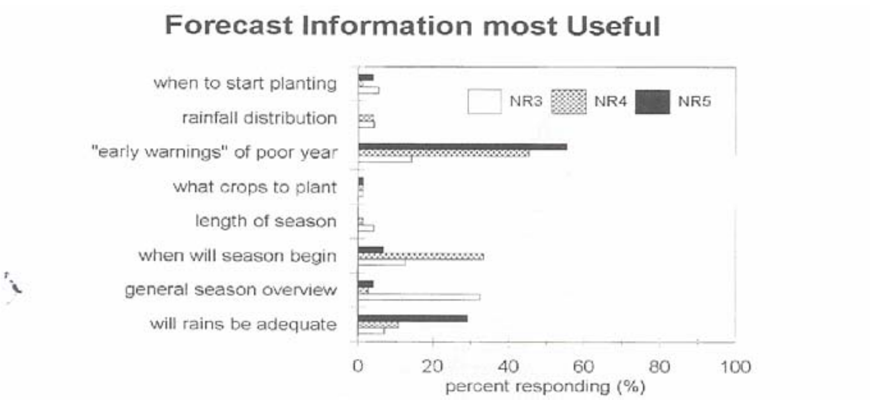

Figure 5.2 Climate information cited as most useful in farm management decisions in advance of the rainy season (Source: Phillips et al. 2001)

The table below summarizes some of the management strategies that farmers are advised to implement depending on the expected season outcome.

Table 5.1 Management strategies that farmer are implementing depending on the expected season outcome

	Cropping Management Strategies	**Livestock Management Strategies**
Expected drought conditions	Select drought tolerant crops such as sorghum, sunflower, cowpeas, cotton etc. Shift some of crop mix to more drought-tolerant varieties and crops Stagger planting dates Implement soil-water conservation techniques increase plant spacing to reduce competition for nutrients Maximize production in seasonal wetlands	Consider speeding up any plans to dispose of old/mature animals Re-consider purchase of new animals Increase amount of silage stored for animals Conserve pastures Moderate consumption of water Implement water-harvesting techniques.
Expected Normal to above normal condition	Planting early with the first rains Selection medium and short season varieties with high yielding potential Diversification of crop mix with some commercial crops, e.g. soya beans, paprika, cotton, tobacco, etc. Staggering planting of selected varieties to minimize risks Split application of fertilizers	Preparing three kraal system to rotate animals Putting in place dipping facilities Making best use of natural pasture Increasing storage of fodder and silage Investing in chemicals against pest and diseases Maintaining recommended population of animals to avoid overgrazing

	Cropping Management Strategies	Livestock Management Strategies
	Early planting the bulk of the crop but stagger planting dates in case there is a long dry spell. Provide a good basal dressing of either manure or inorganic fertilizer in case of an early start. Early plant more high yielding varieties Optimum use of fertilizers – split fertilizer applications as risk of leaching will be high Improve field drainage	

It is important to note however, that in cases where the forecast may be for normal to above normal conditions the forecast does not provide information on the start, cessation and seasonal distribution of the rains. These unpredicted intra-seasonal variations could affect the crop production. It is therefore important to know the mean annual rainfall in each area, the main crops grown and their crop water requirement (CWR). Crop growing period and water requirements may vary from crop to crop as shown in the table below.

Crop	Growing period in Days	CWR (mm)/ growing period
Maize	90 - 140+	500 - 700
Sorghum	90 - 140+	450 - 650
Groundnuts	90 - 140+	500 - 700
Beans	60 - 120	300 - 500
Sunflower	90 - 130	600 - 1000

5.4.3 Current applications and possible impacts of seasonal forecasts: Tanzania's perspective

A study has been carried out in Tanzania (Kihupi et al. 2000) to integrate indigenous knowledge on the seasonal climate forecasts into more formal predictive functions in order to enhance the predictive capability of the respective models. It was strongly felt that just as sea-surface temperatures in the Indian and Pacific Oceans can be used as indicators to predict climate patterns over large areas of Africa, it might be possible to include local indicators based on indigenous knowledge into the same models for higher resolution predictions that are more useful to farmers.

This study has made some inroads into the linkage aspect through identification of appropriate index for the predictant. Correlations were made between the Aridity index (predictant) and other meteorological parameters (predictors). The Aridity Index was chosen because it combines parameters, which describe the quality of the growing season, and then the ratio of the number of wet days to the length of the growing season would be a unity. The product of this ratio and the seasonal rainfall totals gives an indication of the adequacy of water for crop production. So the higher the index the better the growing season. The months of July, August, September and October were selected for correlation analysis. This also happens to be the period when most traditional indicators occur.

The results of the correlations between the identified index and some climatological variables are encouraging. This could provide an insight into the missing link being sought. The predictant has to have the ability to discriminate a season in terms of quality. This is what the farmer wishes to be told of the upcoming season to make them better prepared.

This study found information on climate as key to mitigation strategies at both local and national levels. Forecasting Information needs depend on the sector that uses the forecast and on a particular use within the sector to which the forecast is being applied.

5.4.4 Current applications and possible impacts of seasonal forecasts: South Africa's perspective

Another study was carried out by ARC - Institute For Soil, Climate and Water, in South Africa (Mellart, 2001). The objective of the study was to see if the seasonal climate outlook is useful for the rural small-scale farmer. Selected rural farmers in Maleketu, Thulumahashe and Mangondi were supplied with inputs and production was monitored as farmers plan their agricultural activities and interventions according to the forecast updates. The project proved to be instructive for farmers, extension workers and researchers. The study shows that there is a big difference in the quality of management between farmers. The long range forecast was seen to be ineffective if management was poor. Capacity building for the rural small-scale farmers should therefore comprise an integral part of research and technology development.

A similar study was carried out in Orange Free State Province (Walker et al. 2001). A survey carried out to investigate if farmers/users receive seasonal climate information; understand the terminology used in the forecasts and the ways of information dissemination, identified some problems of communication between meteorological services and users of climate information. The use of technical terms was found to inhibit uptake by the small-scale farmers. Another problem identified were the lack of skills among scientists and extension officers to communicate clearly and to make good connections with the general public. There are no regular training programs for users or farmers so that they are able to understand the information and be able to apply it.

5.5 Terms of Reference (c): To review and recommend ways to use and disseminate optimally the seasonal forecasts and climate prediction in operational agriculture with emphasis on user needs especially in the tropical and subtropical zones

The use of seasonal climate information by communal farmers have increased in recent years in many parts of Africa, This has been attributed to the wide dissemination of the forecast information through various channels such as the print and electronic media. The radio has currently been found to be the most effective means of communication in many parts of Africa. However, the majority of the rural farmers do not have access to the standard media channels such as radios, newspapers, televisions, Internet, e-mail and so on it. It has been sadly noticed that due to the lack of the above-mentioned facilities, climate information usually gets to the remote rural areas too late. For example in Zimbabwe, by the time the forecasts get to them they would have already made their decisions based on traditional forecasting schemes (Phillips et al. 2001; Unangai et al. 2001). There is also need to conduct research into effectiveness of other channels of communicating meteorological information, such as farm demonstrations, farm discussions, farmers ' days, meeting, use of pamphlets, agricultural extension personnel and other farmers and end users (Walker et al. 2001; Unganai et al. 2001).

One of the major setbacks in the application of seasonal climate information in operational agriculture is the communication breakdown between the meteorologists and the users. Meteorologists are packaging the climate information in such a way that it is not user friendly. The use of technical terms and scientific jargon in communication is resulting in failed communication. For example, most rural farmers are illiterate and do not understand the concept of probabilities. This has facilitated misinterpretation and misunderstandings, creating an atmosphere of mistrust. Farmers tend to lose faith in a product, which they do not understand because they interpret the information wrongly and use it inappropriately. To communicate effectively, climate scientists, ought to package climate information in ways that will be easy for farmers to understand. Information intended for farmers should be packaged differently from that for scientists.

Common management strategies implemented by rural farmers in response to seasonal climate information include the timing of agricultural activities such as planting date, weeding, spraying, fertilizer application, selection of crop cultivars and varieties and animal stocking, off sales, movement of animals to unaffected areas, rotational grazing and water conservation among others. However, there is need to avail information on intra-seasonal climate variations which affect the crop production. One common mistake by users is to make a decision based on the first seasonal climate outlook and then ignore keeping track of events. Weather patterns are notorious for changing at short notice. Farmers need to make follow-ups and use these forecast updates. These are essential tools for good agricultural management as they provide crucial information such as the onset and cessation of both wet and dry spells that are currently not being captured in seasonal climate information. A study carried out in South Africa recommended that information on onset and cessation of the season as well as the occurrence of dry spells should be included in the forecast (Mellart, 2001). Agrometeorologists need to regularly monitor seasonal climate outlook information.

Lack of draft power, is another hindrance, as farmers fail to take advantage of the planting opportunities waiting for their turn to plough. Research carried out in Zimbabwe has shown that just under 58% of communal farmers own their own draft power implying that 42% have to wait for their turn to have their fields ploughed (Phillips, et al. 2001). Although forecasting information may be readily available to communal farmers, lack of draft power and resources limit its effective use. Planting opportunities are missed as farmers wait for their turn to plough. Communal farmers should have access to inputs and draft power in order to capture the benefits of seasonal forecast information by making timely and appropriate decisions.

Another possible set back is the level at which information is disseminated. Farmers are demanding a more localized seasonal climate forecast but current advances in seasonal climate forecasts only provides generalized regional climate information however microclimates have the most significant influence on agricultural production. Seasonal climate forecasters should strive to advance the art of seasonal climate forecasting in order to provide farmers with more localized/area specific seasonal products which will in turn improve their decision making process.

5.6 References

Hochobeb, B. 2001. Reliance of rural communities in Namibia on long term weather forecasts and development of effective communication tools and products to transfer the seasonal forecast information for the rainy season from the Namibian meteorological Services to these communities. Consultancy Report submitted to Drought Monitoring Center (Harare, Zimbabwe)

Lucio, F. D. F. 1999. Use of contemporary and indigenous climate forecast information for farm level decision making in Mozambique. Consultancy report. UNDP/UNSO pp17

Kihupi N.I., R. Kingamkono, W. Rwamugira, M. Kingamkono, M. Mhita, and K. O'Brien. 2001. Promotion sand Integration of Indigenous Knowledge in Seasonal Climate Forecasts. Consultancy Report submitted to Drought Monitoring Center (Harare, Zimbabwe)

Mellart E.A.R. 2001. Using A seasonal outlook to mitigate impacts of adverse climatic conditions on rural small-scale farmers in selected communities in South Africa for the season 2000-2001. Consultancy Report submitted to Drought Monitoring Center (Harare, Zimbabwe)

Nanja. D.H. 2001. Final report on the Study of the Southern Province Early Warning and Monitoring Systems (SPESWAMS). Consultancy Report submitted to Drought Monitoring Center (Harare, Zimbabwe)

Phillips, J.G., E. Makaudze and L. Unganai. 2001. Current and potential use of climate forecasts for resource-poor farmers in Zimbabwe. In: C. Rosenzweig, K.J. Boote, S. Hollinger, A. Iglesias and J.G. Phillips (Editors), Impacts of El Nino and Climate Variability on Agriculture. American Society of Agronomy, pp. 87-100.

Shumba, O. 1999. Coping with drought: Status of integrating contemporary and indigenous climate/drought forecasting in communal areas of Zimbabwe. Consultancy report. UNDP/UNSO. pp72.

Unganai L.S. 1998. Seasonal Climate Forecasts for farm management in Zimbabwe. Zimbabwe Dept. of Meteorological Services, Harare, Zimbabwe.

Unganai L.S., R. Mano, and V. Mutikani. 2001. Economic benefits of applying seasonal climate forecasts for farm management in Zimbabwe. Consultancy Report submitted to Drought Monitoring Center (Harare, Zimbabwe)

Walker, S., E. Mukhala, W.J. van den Berg, and C.R. Manley. 2001. Assessment of Communication and Use of Climate Outlooks and development of Scenarios to Promote Food Security in the Free State Province of South Africa. Report submitted to Drought Monitoring Center (Harare, Zimbabwe)

Further Reading

Scoones I. 1996a. Crop production in a variable environment: A case study from Zimbabwe.Exp. Agric.32. 291-303

Scoones I. 1996b. Hazards and opportunities. Farming livelihoods in dry land Africa: Lessons from Zimbabwe. Zed Books, London.

Shumba E.M. 1994. Constraints in the smallholder farming systems of Zimbabwe. P.69-73. In E.T. Craswell and J. Simpson (ed.) soil fertility and climate constraints in dry land agriculture. Pro of the ACLAR/SACCAR workshop, Harare, Zimbabwe., 30 Aug –1 slept 1993. ACIAR Proceedings No. 54.

South African Development Community (SADC), B. S. Nyenzi, B. Garanganga, and S. P. Raboqha. 2000. Proceedings of the First (Pre-SARCOF) Capacity Building Workshop on Seasonal Forecasting for the SADC Region. Pretoria, South Africa, 2 August - 10 September 1999. " Coping with the climate: a Way forward; Preparatory Report and Full Workshop Report, (South Africa) Drought Monitoring Centre, Harare, Zimbabwe.

Unganai L.S. 1996. Historic and future climatic change in Zimbabwe. Climate Research ., Vol 6. 17-145.

CHAPTER 6

USE OF SEASONAL FORECASTS AND CLIMATE PREDICTION IN OPERATIONAL AGRICULTURE IN WMO REGION V

Ms C. Mullen
Australian Bureau of Meteorology, National Climate Centre
GPO Box 1289K, Melbourne Victoria 3001, Australia

6.1 Introduction

The range and complexity of applications of climate information and climate prediction services continues to grow. For Australia, much of the work on climate prediction is done by the Australian Bureau of Meteorology through its National Climate Centre, with a small number of other organisations also active in the area.

In addition, a high degree of collaboration with more specialised state agencies and industry groups is leading to development of services and applications that are tailored more closely to the information and decision support needs of particular sectors. The success of these initiatives is apparent in the uptake of new services and the breadth of climate applications being undertaken, particularly in the agriculture, water management and design sectors.

This report addresses the first four terms of reference of the World Meteorological Organisation (WMO) Commission for Agricultural Meteorology (CAgM) Working Group on the Use of Seasonal Forecasts and Climate Prediction in Operational Agriculture in WMO Region V. These terms of reference are included within the report. With an Australian author, the report has a (natural) bias towards information available for Australia, indicative of both the ease of availability of information and the work being done.

6.2 Terms of Reference (a)

In liaison with the Climate Information and Prediction Services (CLIPS) project, review and summarize the current advances in seasonal forecasts and climate prediction and the products and services relevant to agriculture that are becoming available based on these forecasts;

The climate of the Asia-Pacific region (WMO Region V) is, in part, tied to the El Niño/Southern Oscillation phenomena. Monitoring of the associated Southern Oscillation Index (SOI), as well as sea-surface temperatures (SSTs) in both the Indian and Pacific Oceans provide the foundation for current statistical predictions.

6.2.1 Australia

Since 1989, the Australian Bureau of Meteorology (Bureau), through its National Climate Centre (NCC), has provided 3-month ahead probability-based predictions for rainfall. More recently in March 2000, seasonal outlooks for maximum and minimum temperature were commenced operationally. This information is updated monthly and provided to users via a brief media release available via recorded phone service, pollfax request and the Internet:

- Rainfall: http://www.bom.gov.au/climate/ahead/rain_ahead.shtml,
- Temperature: http://www.bom.gov.au/climate/ahead/temps_ahead.shtml).

Detailed information is available via subscription in publication form or through the Internet (http://www.bom.gov.au/silo/products/SClimate.shtml)

In October 1998, the outlook scheme was upgraded from statistical predictions using the SOI, to use of principal components of Pacific and Indian Ocean SSTs. With the new method, the forecast skill is slightly improved, the output more consistent (less 'jumpy'), and with a slightly longer lead time (issued approximately two weeks before validity period).

Outlooks are augmented with predictions of SSTs from dynamical systems to provide longer-range information. NCC provides a summary of ocean predictions from 12 models (http://www.bom.gov.au/climate/ahead/ENSO-summary.shtml) which is useful in illustrating the uncertainties involved in such forecasts. A full commentary on the current El Niño status (http://www.bom.gov.au/climate/enso/) began in 2001, is updated weekly, and provides a broad update of all available ENSO indicators.

Detailed work was completed in 2001 to provide users with verification statistics for both the BoM's seasonal outlook scheme, and some select coupled climate models, in the form of 'percent consistent' for individual locations (http://www.bom.gov.au/silo/products/verif/). *More details at TOR (C)*

Other regional offices of the Bureau also issue statements particular to their state, notably rainfall advices to water agencies and information on tropical cyclones as related to ENSO.

The Queensland Centre for Climate Applications (QCCA) also produces seasonal rainfall forecasts. These are based on the historical relationship between the 'phase' of the Southern Oscillation Index during the most recent two months, and subsequent rainfall anomalies (http://www.nrm.qld.gov.au/longpdk/lpphases.htm).

Agriculture Western Australia (AGWEST) has been involved in the development of an El Niño prediction system based on mid-latitude pressure indices, which offers a possible longer lead-time than systems based on tropical-latitude indices (possibly 6-9 months lead time). This system is linked to a crop yield forecasting model. (http://www.agric.wa.gov.au/climate/index.htm).

The Commonwealth Scientific and Industrial Research Organisation (CSIRO) uses a dynamical coupled model to make *experimental* long-lead predictions of Australian climate up to 12-months ahead, in particular to forecast the NINO34 index and associated rainfall anomalies for Australia (http://www.dar.csiro.au/res/cm/coca.htm). The Bureau of Meteorology Research Centre also runs a coupled climate model: (http://www.bom.gov.au/bmrc/ocean/results/CM_Forecasts.htm) for SST forecasts at Niño3 and Niño4 up to 9 months ahead.

A number of university groups and private sector organisations also provide specialised prediction services such as Holton: http://users.senet.com.au/~holton7/; Bureau's Special Services Unit (SSU): http://ssu1.bom.gov.au/ssu_web/default.html.

Several web-sites provide a combination of climate monitoring products as well as outlook information that can be used by those in agriculture – notably, the Bureau web site (www.bom.gov.au), SILO (www.bom.gov.au/silo), Queensland Department of Primary Industry (QDPI) Long Paddock (www.dnr.qld.gov.au/longpdk/) among others. The Aussie GRASS (Australian Grassland and Rangeland Assessment by Spatial Simulation) project also supplies climate and resource information specifically for pasture assessment and management via the web. (http://www.nrm.qld.gov.au/longpdk/AboutUs/ResearchProjects/AussieGRASS/)

Recent work has focussed on translating these probability-based climate outlooks into tools that can be used by the farmer. This has included projects using agricultural simulation models, development of software programs for scenario analysis, training workshops as well as a weekly 'interactive' fax-back service. *More details at TOR (C)*

RAINMAN (Rainfall Information for Better Management) is a comprehensive climate analysis software package. Users can evaluate daily, monthly and seasonal rainfall for their locations along with seasonal forecasts based on both SOI and SST (http://www.nrm.qld.gov.au/longpdk/Products/AustralianRainman/index.html). Work is nearing completion on a supplement for seasonal forecasting of stream flow for better planning of water allocation.

The Agricultural Production Systems Research Unit in Queensland has developed a software tool, 'Whopper Cropper', to help predict the production risk faced by growers. This combines seasonal climate forecasting with cropping systems modelling to help producers to choose the best management options. Farmers can investigate the impact of changing sowing date, plant population, nitrogen fertiliser rate and other variables. This provides a discussion support system for further management decisions.

QDPI has developed a Regional Commodity Forecasting System (RCFS) that combines the SOI with a shire based stress-index wheat model. The system assesses the likelihood of exceeding long-term median shire yields, and has potential for use of seasonal forecasts in commodity forecasting for government policy support and for decision making in industry. The system was designed primarily in relation to policy needs and became operational for this purpose in March 2001.

AGWEST has developed, or distributes, a range of climate-related computer programs in conjunction with historical climate records to derive seasonal rainfall probabilities, potential crop yield, frost risk, flowering times and planting opportunities for Western Australian pastoralists.

'Oceans to Farms' (a collaborative CSIRO project) has investigated connections between ocean temperatures and farm management. A lagged statistical relationship has been established between ocean surface temperature and plant growth, and it is now possible to make seasonal predictions of future growth. Assessments of this forecasting approach for the northern Queensland grazing industry reveal possible production increases of 16 per cent as well as 12 per cent reduction in soil loss. These benefits exceed those obtained using a forecast based on the SOI.

The Bureau's Research Centre has been investigating techniques to monitor and predict on time scales of 10-40 days. An experimental monitoring/forecast system for equatorial regions has been established and is being tested. Preliminary results from this scheme indicate that precipitation variations can be skilfully forecast out to about 15-20 days ahead. (http://www.bom.gov.au/bmrc/clfor/cfstaff/matw/maproom/OLR_modes/index.html)

Preparatory work has been done by the Bureau of Meteorology for a project proposal to AusAid to improve climate prediction services in some South Pacific Island countries. Following the successful installation of a pc-based climate prediction service in Fiji, this project would develop a more comprehensive system for installation in a few countries using a dedicated project officer. Such a capability is in great demand in the Pacific Island countries, most with developing economies, and would provide useful services for planning and sustainable development. The project proposal is at planning stage only.

Following a recommendation made at the Sixth SPREP Meeting of Regional Meteorological Services Directors in Tahiti (1999), the 'South Pacific Seasonal Outlook Reference Material bulletin' has been developed. This bulletin is produced by the Bureau of Meteorology and is available on a monthly basis on request via e-mail. The reference material discusses the current state of ENSO with future outlooks and possible impacts in the South Pacific region, as a tool to assist island nations in their local climate decision making processes.

6.2.2 New Zealand

Details of climate prediction services provided by the National Institute of Water and Atmospheric Research via the National Centre for Climate Monitoring and Prediction (NCC) in New Zealand are available at http://www.niwa.cri.nz/ncc/ '*Climate Update'* presents a monthly summary of New Zealand's climate, including rainfall, temperature, river flows and soil moisture, together with an outlook for the next quarter and topical articles.

'The Island Climate Update' is a regular newsletter to provide Pacific Island Countries with seasonal-to-interannual climate information and is distributed for the South Pacific - see www.niwa.cri.nz/NCC/ICU/index.html . This includes a regional teleconference each month between Papeete, Nadi, Noumea, Auckland, Wellington (NIWA) and Melbourne (Bureau)

6.2.3 Fiji

The Fiji Meteorological Service (FMS) runs a prediction model, known as the FMS Rainfall Prediction Model (RPM), based on schemes which have run successfully in the Australian Bureau of Meteorology's National Climate Centre (NCC). These are statistical schemes based on the relationship between the SOI and subsequent three months rainfall totals. The initial forecasts were for the western and northern divisions of Fiji, becoming operational in July 1999. In March 2000, this model was modified by Fiji to include twenty-five individual sites covering all four divisions in Fiji. In each case the probability of low, medium and high rainfall in this following three-month period is provided. There are two sets of forecast for each site: the first scheme uses the SOI averaged over the most recent three month-period and the second scheme uses the SOI averaged the most recent six-month period preceding the forecast period. Only results from RPM's first scheme have been incorporated in FMS's Monthly Weather Summary (MWS) since January 1999.

RAINMAN has also been utilized by FMS for rainfall forecasting since August 1999. This package also incorporates the use of SOI to test its effects on the probability of rainfall, except it accommodates up to a month to twelve months. Initially the forecast was provided for the four divisions as whole in the MWS; later nineteen individual sites around the country were included in the package, and the monthly probabilities for the following three months are now included the summaries. The rainfall forecast can be accessed on the FMS's website, http://www.met.gov.fj/MWS.html.

Skill levels of the RPM in Fiji exceed levels obtained anywhere in Australia, with high skill during the wet season (November to March), decreasing during the dry season (May to September) and during the transition months, April and October. The skill level for the Australian RAINMAN package is similar to RPM. Skill tests for the period from 1996 to early 2000 show 6 to 10 out of 12 correct forecasts annually. The skill level is lower for the monthly forecast than for the three-month period forecast.

Results from both models are now included in the MWS in tabular form i.e. upcoming three-month period forecast produced from RPM, and monthly rainfall probabilities for the same three-month period produced from Australian RAINMAN. The monthly rainfall probabilities were introduced in the MWS for May 2000 after a request was made by users from the forestry and the sugar cane sectors during a seminar on the rainfall prediction models ran by CSD in May 2000. Three-month period forecast was not sufficient to meet their planning needs for planting, harvesting or logging. There has been increasing demand for quantitative forecast over smaller areas by the agricultural and the forestry sector. FMS now provides forecast in schematic format. It also provides Fiji's forecast to the Island Climate Update bulletin produced by New Zealand. On request, RAINMAN is used to provide rainfall forecast for up to a year.

Though climate forecasting is relatively new to many island countries, its application is now widely accepted. Moreover, island governments have formally expressed a need for assistance in building the capacity of meteorological services and climate information users to use climate forecast information, and for greater access to climate forecast information on a regional level. There is also a need to develop tools for "down-scaling" climate information at a regional scale to local level forecasts of rainfall and tropical cyclone forecasts.

6.2.4 Pacific ENSO Applications Center (PEAC)

PEAC undertakes several types of coordinated research and applications activities. The research effort has been aimed primarily at developing statistical rainfall models and synoptic climatologies.

PEAC directed its research effort at the development of canonical correlation analysis (CCA) models. The *Pacific ENSO Update* newsletter and corresponding website, http://lumahai.soest.hawaii.edu/Enso began in August 1996 and is published and distributed in hard copy and on the website four times a year beginning in August 1996. This covers jurisdictions in the North Pacific and complements the Island Climate.

In addition, a rainfall atlas '*A Precipitation Climatology for Stations in the Tropical Pacific Basin: Effects of ENSO'* was published in February 1998. The atlas provides analyses of rainfall for sixty-six stations throughout the Pacific Islands region using data for the period 1955-1996. For each station, rainfall histories are graphed, and mean monthly rainfall amounts for "normal," El Niño, and La Niña years are presented in a variety of forms.

6.2.5 South Pacific Applied Geoscience Commission (SOPAC)

SOPAC organized "ENSO Impact on Water Resources in the Pacific Region Workshop" in Nadi, Fiji, from 19 to 23 October 1999, attended by about 80 participants from 23 countries. The purpose of the workshop was to introduce national water managers, disaster managers and meteorological services to the use of climate information and ENSO forecasting in developing response and mitigation plans with the objective of reducing the impact of future droughts in the Pacific region. The simulation exercise showed both the value and difficulties in climate analysis and forecasting and response planning. Clearly, the meteorological services in the region have the ability to make better use of climate analysis and forecasting techniques. More effective communication between meteorological services and disaster and water management agencies is needed. Some governments have the internal capacity to provide climate forecasting and information services. However, assistance will be required through regional organisations to increase local capacity and make optimal use of climate information from Australia, New Zealand, the United States of America, the World Meteorological Organization, and the International Research Institute for Climate Prediction.

Participants were greatly encouraged by efforts to improve climate information services for the Pacific Islands discussed in presentations made by the World Meteorological Organization on the CLIPS project and the South Pacific Regional Environment Programme. Interest was expressed to incorporate European climate models to enhance local and regional climate predictions.

6.2.6 South Pacific Regional Environmental Programme (SPREP)

SPREP with WMO and Météo France organized a Regional Workshop on Climate Information and Prediction Services (CLIPS) in Tahiti, French Polynesia, which preceded the Sixth SPREP Meeting of Regional Meteorological Services Directors (6RMSD), from 26 to 30 July 1999.

6.2.7 Indonesia

In Indonesia, the 1997-98 El Niño-related dry conditions led to large-scale damage mainly due to uncontrolled forest fires in Sumatra and Kalimantan. ENSO may have significant implications for the agricultural and food security sector. This is a very important issue for the government, which is still struggling to overcome an economic crisis.

Forecasts indicating the possible onset of an El Niño event were available to the Indonesian Bureau of Meteorology and Geophysics (BMG) as early as late 1996. BMG incorporated this information into a dry-season seasonal climate forecast for the entire country, which was issued to all relevant user departments at national and provincial levels in March 1997. The forecast information was communicated through the existing information network, which is utilized for routine administrative functions. No urgency was attached to the timely flow of information from national to provincial to district to sub-district levels of various user departments.

In the agriculture sector, no major interventions were undertaken. In the forestry sector, the Ministers of Environment and Forestry and a number of provincial governors called on everyone to be alert and to take action to prevent forest and land fires. However, these warnings were not followed up and fires began in early 1997.

6.2.8 Papua New Guinea

The National Weather Service of Papua New Guinea has limited human and material resources and is significantly under-funded. It is short of professional staff and has only a limited climate monitoring capability. The onset of the 1997-98 El Niño event, while undoubtedly communicated to the Service, does not appear to have been monitored formally for some time. It was not until August 1997 that a National Weather Service staff member returning from studies overseas could be spared to examine the El Niño reports coming from overseas, then was able to prepare a briefing for the government and a report on the drought and severe frost.

Papua New Guinea lacks an effective system for collecting, organizing, analysing and disseminating disaster management. In 1997, the only hazard warnings were for tropical cyclones. There was no formal system for reporting hazard impacts on any part of the country. With few indigenous scientists, Papua New Guinea has lacked the resources to maintain the momentum of research since independence. Since the 1997-98 El Niño-related drought, the National Weather Office has been conducting low-level research on the possibility of predicting serious drought by comparing the accumulated total rainfall in previous wet season at Dar in Western Province with year-to-date rainfall readings.

6.3 Terms of Reference (b)

To survey and summarize, using appropriate case studies, the current applications and possible impacts of seasonal forecasts and climate prediction in agriculture, forestry and livestock management;

B1: A case study of tactical decision-making for a dryland grain/cotton farmer (Meinke and Hochman, 2000)

B2: Example application – sugar-cane industry (Everingham et al., 2002)

B3: Managing climate variability in grazing enterprises: a case study of Dalrymple shire, North-Eastern Australia (Ash et al., 2000)

B4: Seasonal climate forecasting and the management of rangelands: do production benefits translate into enterprise profits? (Stafford Smith et al., 2000)

An effective application of a seasonal climate forecast is the use of forecast information that leads to the change in a decision that generates improved outcomes. A seasonal forecast has no value if it does not generate changed decisions. But to be effective the decision changes must produce positive changes in value by improving the relevant aspect of system performance targeted. In agricultural, this most often relates to profitability, use and conservation.

Primary producers use climate information to assist with many decisions on seasonal to interannual time-scales. The decisions relate to: crop choice (eg wheat if good conditions expected; sorghum if drier); choice of cultivar (early or late flowering); mix of crops; fertiliser use; pest and disease control; timing of the harvest; irrigation scheduling; the area to crop (and/or rotation of fields); timing and amount of tillage; and stocking rates. Strategic planning and marketing decisions mostly use climate information for the next year.

6.3.1 A case study of tactical decision-making for a dryland grain/cotton farmer Meinke & Hochman (2000)

This is a case study for a dryland grain/cotton farmer (DCF) on the southern Darling Downs, Queensland. DCF has used climate forecasting in tactical crop management decisions for several years and has recently intensified and streamlined his efforts. He takes the seasonal forecast into account for all his management decisions and aims to increase the proportion of cotton in his rotational system without compromising the long-term sustainability. This approach aims to maximise the profitability of the whole farm operation. To achieve this, several factors are vitally important. Keeping in mind that water is the most limiting resource in this environment, the factors are:

- Avoiding soil fertility decline
- Avoiding erosion and run-off
- Maximising water infiltration
- Developing a surface management system that allows sowing a crop after even minor rainfall events (10mm) in order to be as close as possible to the optimum sowing date

Many of the crop management strategies used by DCF are not a direct consequence of a seasonal forecast, but it is difficult to clearly separate the issues. DCF pointed out that since he started following and using the seasonal climate outlook, his whole thinking about crop and cropping systems management has changed. Although he was always aware of the importance of conserving water and would have implemented management strategies such as no-till regardless of the availability of seasonal outlooks, the speed and thoroughness of the implementation of these strategies was greatly affected by the forecast.

6.3.1.1 Nitrogen management

DCF uses simulated 'target yields' for wheat and sorghum to optimise his nitrogen strategy. These target yields are determined based on the amount of stored soil moisture prior to sowing, historical rainfall records and the long-term rainfall outlook. From this, they estimate the 10th percentile of achievable yield in a given season. Nitrogen requirements are then determined based on the available background nitrogen in the field and the appropriate amount of nitrogen is applied.

Although DCF always aims to reduce evaporative losses by maximising the no-till area and by applying nitrogen in the least soil-disturbing way (eg 'knifing' nitrogen into the soil rather than cultivating), this becomes imperative if the outlook indicates a likely dry period. He sees adequate nitrogen nutrition in dry seasons as particularly important to establish a good root system and increase water use efficiency.

6.3.1.2 Managing frost risk in wheat

Frost at or after anthesis can lead to considerable yield reductions in wheat. The anthesis time that corresponds to the highest yield potential is also the period of maximum frost risk. A negative SOI value by the end of May alters the frost outlook significantly with the chances of a late damaging frost for wheat rated at higher than normal. Although such developments are not certain until (usually) the end of May, a carefully worded El Niño alert was issued in April 1997. Based on this information, DCF adjusted his winter crop management. He prepared his wheat cropping area so that he was able to sow some wheat at the earliest planting opportunity in late April. To spread the frost risk, he only planted about half the area designated to wheat at this time – the rest was planted late May. The 'gamble' paid off and the early-sown wheat yielded close to 5 t ha^{-1}, amongst the highest yielding wheat in the district.

6.3.1.3 Marketing

For DCF grain marketing was one of the most profitable applications of seasonal climate forecasting in 1997. There are two elements to it:

A lag relationship between the SOI phase and futures price of some commodities has been found. This reflects that under certain SOI conditions production is likely to deviate from the long-term average. Markets adjust to these changes in supply by adjusting prices. In conjunction with estimates of farm-specific production also based on SOI phases, this information is directly applicable to determine the best marketing strategy by either selling or buying futures and/or options (hedging).

Markets also react directly to the forecast. Again, producers can utilise this knowledge by buying and selling futures or options and even by anticipating currency movements. DCF has applied this knowledge with great success in the 1997 winter season.

6.3.1.4 Specific management actions during the 1997 and 1998 seasons

Following is a detailed summary of DCF's actions/decision that were affected by the seasonal climate outlook. Using output from dynamic crop simulation models, DCF evaluates alternative management strategies to identify the least risky and/or the most profitable options. In 1997, DCF took the following actions:

- Maximised no-till area
- Applied nitrogen fertiliser early to allow planting on stored soil moisture at the most appropriate time
- Planted some wheat on 20 April, the rest in late May to spread frost risk;
- Applied 75 kg ha^{-1} of starter nitrogen to ensure good root establishment;
- Cultivated *early* for 'pupa bust' (insect control) to save as much soil moisture as possible for a barley double crop (i.e. winter crop sown straight after summer crop). This crop yielded 2.5 - 3kg ha^{-1}, a rare yield level for a double crop even under favourable climatic conditions;
- Conducted early weed control to save moisture;
- Sowed some faba beans and chickpeas as alternative crops to wheat to spread risk (frost risk and different water use pattern);
- Tactically applied additional nitrogen fertiliser at varying amounts based on nitrogen already applied and likely crop performance based on the seasonal climate outlook;
- Did NOT forward sell grain because of El Niño outlook (yield unknown, but prices usually rise).

During an evaluation session in late 1997, DCF rated all these measures as successful. His yield and grain quality were substantially above the district average and he attributes this positive result largely to his ability to include climate forecasting into his decision-making.

To be most effective, the approach shown here requires an understanding of the probabilistic nature of the information provided, whereby producers must not become disheartened by any perceived ‘failure’ or ‘win’ of the forecast in any given season…The approach must be used consistently for many season to truly benefit from it. Further, it must be integrated into the whole decision making process as one of many management tools.

6.3.2 Example application – sugar-cane industry

Seasonal climate forecasting tools are increasingly used in risk management for annual cropping systems such as peanuts (Meinke and Hammer, 1997), maize (Singels and Potgieter, 1997), wheat (Hammer et al., 1996) and cotton (Dudley and Hearn, 1993). Everingham et al. (2002) more recently investigated the potential applicability of climate forecasting for perennial crops and sugarcane in particular.

This approach advocates a whole-of-systems approach for using seasonal climate forecast systems to improve risk management and decision-making capability across all sugarcane industry sectors. The application of this approach is outlined for decisions relating to yield forecasting, harvest management, and the use of irrigation. Key lessons learnt from this approach include the need for a participative R&D approach with stakeholders and the need to consider the whole industry value chain. Additionally, there is the need for climate forecast systems to target the varying needs of sugarcane industries.

By considering a system for the whole of industry, the integration of seasonal climate forecasting with management strategies has the potential to benefit sugar industries in many areas, and in particular by:

- improved on-farm profitability, e.g. better use of scarce water resources
- improved planning, e.g. wet weather harvest disruption, early season sugar, better scheduling of milling operations
- enhanced industry competitiveness, e.g. more effective forward selling of sugar

The research approach is demonstrated as part of three case studies focusing on irrigation planning, harvest management and yield forecasting.

For irrigation planning, given limited (sometimes insufficient) water allocations, combined forecasting and field work tried to specifically determine if irrigation could be timed to coincide with periods of most severe water stress during the season. They also looked at whether or not irrigation applied during these periods is better than a grower’s skill in using limited water. Results showed that there was only one moderate stress period during the six-month experiment, which was identified correctly by the cooperating grower and the forecasting method alike, showing no benefit from the irrigation forecasting technique in this season. Growers participating in this research agree that forecasts of optimum timing for limited irrigation may not benefit the better growers but will assist many who do not use their allocations at the right time for fear of running out of water too early.

For harvest management, work focussed on prediction of wet days at harvest time which might interrupt the schedule. Results showed that seasonal climate forecasts can add value to decisions influenced by high rainfall events in October-November, but there is less skill associated with forecasting wet days for May-June. Growers participating in this research acknowledge that if these climate forecasts had been used in planning operations for the 1998 season, an early warning of the excessive rains experienced may have been heeded, since the SOI phase was ‘consistently positive’ from July 1998 through to March 1999. This would have had beneficial impacts from the farm through to the marketing sector of the Australian sugar industry for the 1998 season and subsequent seasons to follow. Climate forecasts for key periods during the harvest season are now published in the Australian Canegrower, a magazine distributed to an industry audience comprising more than 7000 people.

With respect to yield forecasting, some progress has however been made on the relationship between ENSO and sugarcane productivity in Australia. Everingham et al., (2001) examined the relationship between yields and SOI phases for Australian sugar yields, and found that the 5-phase SOI system offers the potential to improve sugarcane estimates but success varies with geographical location and SOI phase.

The most important learning was that we have to go beyond the ‘science’ of climatology and link this with participative implementation processes to realise the benefits of emerging knowledge to industry. After successive meetings, key decision points and the necessary climate forecast outputs were defined. This embryonic research to date, has highlighted significant potential benefits for sugar industries worldwide. The challenge remains, for these benefits to continue to be realised in practice.

6.3.3 Managing climate variability in grazing enterprises: a case study of Dalrymple shire, north-eastern Australia

Ash et al. (2000) examined approaches to managing climate variability in the Dalrymple shire of north-east Queensland. The forage-animal production model GRASP was used to evaluate the production and resource implications of grazing management and seasonal climate forecasting strategies. In this study, five forecasting strategies were assessed at each of nine test rainfall stations in Dalrymple shire. Forecasting strategies used were: (a) spring SOI, (b) spring SOI phases, (c) an SOI phase system “tuned” to Charters Towers rainfall, (d) winter Pacific Ocean sea surface temperatures (EOF analyses), and (e) winter Pacific and Indian Ocean sea surface temperatures (EOF analyses). Stocking rates were adjusted annually according to analogue year types provided by the forecasts. In forecasts “dry” years stock numbers were reduced by 50% and in “wet” years they were increased by 30%. Stocking rate changes were made in either November, when all the forecasts were available, or in June, which assumes some improvement in forecasting lead time, particularly for the SOI.

Results from the analyses show that:

- Seasonal climate forecasting provides more benefit to animal production when the forecasting information is available in June rather than November

- The relative value of forecasting is greater for constant grazing strategies than for flexible ones

- Increased animal production derived from applying a forecast is not at the expense of the resource base and if increased animal production is not he desired aim of the forecast then significant reductions in soil loss can be achieved

- Using localised forecasts does not provide any extra skill in production simulations

Despite the demonstrated benefits of using a forecast strategy based on the SOI, there is considerable reluctance amongst producers to adopt such forecasts. A producer survey indicated that even if more reliable forecasts were developed, most would wait until extreme events had an impact on their enterprise before making critical stocking decisions. A grazing trial has been established that will compare grazing management strategies, including a seasonal forecasting strategy, which should assist in demonstrating the potential benefits of seasonal forecasting. Even in the absence of seasonal forecasts, grazing management in the rangelands of Australia could be vastly improved through better incorporating existing understanding of climate variability into stocking decisions. This paper shows that further value maybe added through the application of seasonal forecasting but that perhaps this added sophistication should only be contemplated after basic grazing management principles are incorporated into whole property planning.

6.3.4 Seasonal climate forecasting and the management of rangelands: Do production benefits translate into enterprise profits?

There are increasing opportunities for farmers to use climate forecasts to assist with their management of grazing enterprises, but the value of the forecast needs to be assessed in the whole enterprise context, with the realistic consequences of management decision-making. Stafford Smith et al. (2000) used a linked model of pasture growth (GRASP) and herd dynamics and property economics (Herd-Econ) to simulate whole enterprise management on cattle stations in north-east Queensland. The simulation realistically included the costs and benefits of buying and selling stock, and the impacts of differing stocking rates on resource condition and animal production rates (growth, death and birth rates). A Constant stocking rate and a trading Reactor strategy was examined over the 104-year weather record, then 6 or 12 month forecast information was added to the farmers' decision-making. They found that – In general the optimal level of response to a forecast (increasing stock numbers in good years and decreasing them in bad) increased with increasing certainty. An inappropriate response to the forecast could be worse than no response, highlighting the sensitivity of forecasting advice to this factor. The differences in cash flow between different levels of response to a forecast could be considerably larger than the difference between strategies.

At the optimal response levels, forecasts provided a modest benefit in cash flow over baseline strategies, with more benefit to be gained from a 12 month forecast than a 6-month forecast. The same level of cash flow could be achieved for a much lower risk of environmental degradation (as measured by a soil loss index) with forecasting; however, if advantage was taken of an increased cash flow, then the risk of soil loss changed little. The benefits found in production per unit area do not translate to economic output at the whole enterprise level in a simple way.

The outcomes were sensitive to changes in market prices. In general, trading strategies (Reactor, and 6 or 12-month forecasts) were relatively more favoured over a Constant stocking rage strategy as sale prices rose, and especially as the margins between sale and purchase price increased. Higher stocking rates were also favoured at higher prices in Reactor strategies.

The study highlights the importance of assessing the value of forecasts in the context of the whole management system. There are many other aspects of risk management from which producers could benefit before forecasting becomes the limiting factor in management. However, a seasonal forecast with current skill has some value for production and resource protection when used to trigger appropriate responses; future developments should deliver more.

For more case study information, see the special edition of *Agricultural Systems* on 'Applying Seasonal Climate Prediction to Agricultural Production' (Everingham et al., 2002).

6.4 Terms of Reference (c)

To review and recommend ways to use and disseminate optimally the seasonal forecasts and climate prediction in operational agriculture with emphasis on user needs especially in the tropical and subtropical zones;

Optimal use and dissemination of climate information necessarily involves a number of avenues.

6.4 Dissemination methods

Is used including fax, phone, postal publications and internet. One of the main channels is via the mass media, which reaches a large audience, but has limitations as messages can be abbreviated, misinterpreted or 'sensationalised'. Nonetheless it is still one of the major channels for information distribution so continuing education and 'tailoring' of the messages is important.

6.4.1 Identification of user needs

And on-going dialogues are essential to optimal usage. Most agencies in Australia are involved with field days, presentations, seminars, and conferences where user needs can be discussed. Other mechanisms used to determine user needs include:

- A one-off conference, 'Cli-Manage' held in October 2000 to draw attention to the Bureau's climate services and to assist with identifying future service requirements (Power et al., 2001). Proceedings are available in hard copy (order form at ftp://www.bom.gov.au/anon/home/ncc/cli2000/climanage-orderform.doc).

- Small focussed workshops with industry representatives to exchange information. 'Climate Outlook Fora' have recently been held annually with users from water, fire and agricultural agencies to gather feedback on information required and decisions taken, so as to better tailor future developments.

- User surveys, e.g. three written surveys have been conducted with users of the 'Seasonal Climate Outlook' service to better tailor the service to their requirements. On average, respondents to recent surveys have rated the outlooks as being somewhere between "occasionally useful" and "generally useful".

- A workshop in 'Participative Decision Making with Farmers' in April 2000 as part of the ACIAR project drew 35 participants including farmers and collaborating scientists from countries such as Australia, India, Indonesia, and Zimbabwe

Requests received from users – one method rapidly growing in popularity is feedback via e-mail to the Bureau's web site:

- Communication with field staff

- Mechanisms of education that involve interaction with users also assist in identifying user needs (some detailed below).

In the Pacific region climate forecasting and its applications are relatively new to many island countries. Lots of people still have doubts about climate forecasts and they are reluctant to accept them for practical purposes. NMSs need to break this barrier first before they can expect the users to apply the climate predictions in their respective fields. Establishing National Climate Outlook Forum and/or Regional Climate Outlook Forum may be the answer to enhance the interaction between the NMSs and the users, and set a platform for information exchange and feedbacks from both the parties through active dialogue.

6.4.3 Education

On the availability of climate information and 'what it actually means' is vital, etc., with written material available as pamphlets and books. The Internet is being increasingly used for education, also to answer queries (via e-mail). Some agencies conduct short (one-day)

‘Climate Workshops’ (e.g. QCCA, NSW Ag). QCCA has established a dedicated education position to develop educational tutorials, climate workshops, a teacher’s manual on ‘Climate Weather and Agriculture’ and a nationally-accredited education unit on developing climate risk management. On-going education of staff is also important to ‘train the trainer’ in new products and methodologies. The Bureau of Meteorology had conducted ‘Advanced Climate Courses’, held every 2-3 years, for staff to update and expand their climate knowledge. Additional places are also created for staff from other organisations who are users of climate information (e.g. agricultural extension officers) to attend.

6.4.4 Assessment of forecast skill

Verification gives users a guide to outlook accuracy. The Bureau (through NCC) has recently developed a website of dynamic, Australia-wide maps of ‘Percent Consistent’ (http://www.bom.gov.au/silo/products/verif/). ‘Percent consistent’ is defined as the percentage of years in which the category (above or below normal) favoured by the probabilities in the outlook was subsequently observed. By clicking on any location in Australia, a table then shows all past outlooks for that location. Users are then able to make a detailed assessment of the reliability of the Seasonal Climate Outlook for that region. For internal purposes, the Bureau also uses other verification measures eg LEPS, ROCS.

Tailored information for point locations (not districts) that is industry-specific is frequently requested. Agricultural simulation models combined with probabilistic climate forecasting are important tools to allow objective evaluation of alternative decisions at the farm, marketing or policy level. There is a lot farmers can do to manage climate better, but climate forecasts are only a small part of the potential improvements to be made. Forecasts need to be integrated with other practices, rather than being treated in isolation.

Presentation of the information is also important – misunderstanding of probability forecasts. Communication also needs to deal with consequences of wet years (for Australia – La Niña) – often focussed only on the chance of *low* rainfall leading to poor production. The Bureau has included some education pages on the web site to provide some further explanation on probabilities and other terms (e.g. http://www.bom.gov.au/lam/Students_Teachers/climprob/rainprbsec.shtml)

The Bureau’s Seasonal Climate Outlook is available on the SILO website, giving rainfall and temperature outlooks for the next three months (http://www.bom.gov.au/silo/products/SClimate.shtml). Considerable effort into tailoring the information to individual user (location) needs has been undertaken including a new interface that references all weather/climate information from the Bureau for the chosen location. The SILO web site was established particularly aimed at the agricultural sector – the most popular product being ‘meteograms’ which provide a 7-day weather outlook for temperature, rainfall etc. for any location in Australia. The Bureau’s Special Services Unit (the commercial arm of the Bureau) has recently joined forces with Telstra (telecommunications) to produce ‘Premium Weather’; weather products tailored for the Agricultural sector. (http://www.telstra.com/info/premiumweather/)

Climate information for primary producers needs to be readily accessible and timely. One particularly successful model is the ‘Climate Risk Yield and Information service’, developed over the past 6 years by South Australian Research and Development Institute (SARDI). Tools and services SARDI provides or supports include Climate Risk Management Workshops for delivery across southern Australia; and Climate Risk Management Decision Support trials incorporating the Climate Risk and Yield Information services. This weekly/fortnightly fax back service has been developed where farmers fax in their daily rainfall records to a SARDI contact person. Individual details are then put into a series of models with results faxed back on location and paddock-specific outputs for each farmer. Tailored output includes wheat yield predictions and helps decision such as how much crop area to sow, when to sow and how much nitrogen to apply. Both the training workshops and the faxback service can also be used to distribute or trial new climate information, tools, services, models and developments.

With several agencies involved in climate predictions and applications in Australia, a 'united voice' is needed during an ENSO event so that potentially conflicting information from different models does not confuse the user or degrade the data provided. The 'El Niño Status group', consisting of representatives from core agencies involved in climate prediction and application/impact work, is activated in climate extremes to ensure a unified approach and encourage referral to the Bureau for information. If indicators are strong around May that an El Niño event is likely, then a joint media conference with representatives from the status group plus other organisations (e.g. National Farmers Federation) would be held to provide information on the full spread of climate prediction and impact queries.

Accuracy of seasonal forecasts is highly valued; however the 'best' forecasts require other elements. They also require continued dialogue between supplier and user resulting in information appropriate to decision making, personalized forecast delivery in addition to enhanced understanding through regular training/updates. After all, farmers will only use what they think they need.

6.5 Terms of Reference (d)

To assess the potential of predictions in Early Warnings to reduce the adverse impacts of climatic events on agriculture, forestry and livestock management;

As understanding of ENSO improves and model skill gradually increases, the potential for providing early warning of impacts also improves. This will be enhanced by improved communication of information, including the user's understanding of probabilistic forecasts and the limitations of long-range forecasting. An effective system for distribution of these warnings is essential, including good linkages with media organizations. Recognised actions for the user to take once this information is received will be invaluable to their success.

Papua New Guinea lacks an effective system for collecting, organizing, analysing and disseminating disaster management. The disaster management system is underdeveloped and under-resourced. This situation is about to change, as a five-year Australian-funded development program was due to begin in 2001

PEAC staffs are convinced that in many countries and for many sectors, the coupled models used to forecast ENSO events provide adequate lead-times to develop a response. Some climate modellers have said that issuing a forecast in June of the first year is "now-casting" because you are in the event. But, in terms of local climate impacts in the Western Pacific, these now-casts provide five or six months of lead time before the rainy season and typhoon season set in. However, an understanding of local climate variability and its relationship to both large scale climate cycles like ENSO and to local impacts must be understood in order to make that judgement;

PEAC also began working with what is now the Disaster Management Unit of the South Pacific Applied Geoscience Commission (SOPAC) on development of methods to assess the impact of the 1997-1998 El Niño and develop drought mitigation plans for the South Pacific. PEAC staff provided SOPAC with an impact assessment protocol that was used in Fiji and assisted with the design and facilitation of the impact assessment and mitigation planning workshop held in July 1999. PEAC also worked with SOPAC to plan and facilitate a regional workshop in Fiji and other countries in the South Pacific on the use of disaster impacts assessment information, climate analysis and climate forecasting for disaster response and mitigation planning held in October 1999 in Fiji.

PEAC's collaboration with the Disaster Management Unit at SOPAC has resulted in a manual developed with support from the Center of Excellence for Disaster Management and

Humanitarian Assistance in Honolulu. The manual will include methods for (1) quantifying the impacts of cyclones, floods, and droughts on a wide spectrum of social and economic sectors, (2) calculating return periods for these extreme events in relation to historical ENSO events, (3) using climate forecasting capacity to respond more effectively to ENSO-related droughts and storms, and (4) development of more effective disaster response and mitigation plans.

Both the Australian Bureau of Meteorology (http://www.bom.gov.au/bmrc/ocean/results/CM_Forecasts.htm) and CSIRO (http://www.dar.csiro.au/res/cm/coca.htm*)* run coupled climate models in research mode which may provide early warning of future extreme climate events, well in advance. AGWEST has been involved in the development of an El Niño prediction system which may offer a longer lead-time than systems based on tropical-latitude indices (6-9 months).

The Bureau's National Climate Centre has adapted (for internal use only) an El Niño alert system. This system is divided into 3 stages. Each stage has several objective criteria that, if matched, result in a specified level of alert. Stage 1 is an “El Nino Watch”, and is the lowest stage. Stage 2 is “El Niño Warning”, suggesting that conditions are more advanced towards an El Niño. Finally, Stage 3 is an “El Niño Declaration”, meaning the objective criteria for a true El Niño state have been reached. It is proposed that only at this stage would media comment be made. The sample scheme is detailed at Attachment 1. The El Niño alert system is currently for internal guidance only.

6.6 Summary

Seasonal prediction work has made significant advances in recent times, although more work is needed in applications to take full advantage of advances in prediction.

For any forecast to be effective, the information provided must alter a decision in a positive way. Seasonal forecasting can be used operationally and does influence tactical crop management. The range of this information ranges from very general to highly specific. Further, for producers to apply such knowledge, they need to have ownership of the issues. This requires communication processes that are well targeted and range from one-to-one scientist/producer interactions (co-learning) to group interactions to general media releases.

Priority will continue to be given at the Australian Bureau of Meteorology to the continued use of new and improved technologies to provide world class monitoring and prediction services. Improved understanding of climate variability, and application of appropriate management techniques will be crucial to achieving sustainable development goals in the 21st century.

6.7 El Niño Alert System Criteria

Stage 1 (Watch)

- Climate system in neutral or declining La Niña state
- At least four of the first ten SOI analogues show falling SOI during the next four months
- At least four of twelve internationally recognised ENSO forecast models show warming to at least a +1 standard deviation anomaly in NINO3 by the late austral winter or spring
- Can be revoked
- Normally issued in late austral summer or autumn

Stage 2 (Warning)

- Clear warming trend in NINO3 during previous three to six months

- Majority of twelve internationally recognised ENSO forecast models indicating warming to at least a +1 standard deviation anomaly in NINO3 by the late austral winter or spring

- Observed SOI below -7 for two consecutive months, OR observed average SOI below -7 over two months

- Low-level westerly wind anomalies analysed over the western equatorial Pacific for two successive months

- Normally issued late austral autumn or winter

Stage 3 (Declaration)

- NINO3 anomaly has reached +1 standard deviation

- Majority of twelve internationally recognised ENSO forecast models showing anomalies of at least +1 standard deviation anomaly in NINO3 until the end of the year

- Observed SOI below -7 for at least three consecutive months, OR observed average SOI below -7 over at least three consecutive months

- Low-level westerly wind anomalies analysed over the western equatorial Pacific for at least three successive months

- Normally issued austral winter or early spring

How would it work?

- Each stage publicised via the SCO media release and WWW page
- Advice sent to the relevant Commonwealth departments
- Information about the Alert System (as above) kept on a separate web page

Glosarry of Acronyms

AGWEST	Agriculture Western Australia
APSIM	Agricultural Production Simulator
APSRU	Agricultural Production Systems Research Unit
Bureau	Australian Bureau of Meteorology
BMRC	Bureau of Meteorology Research Centre
CSIRO	Commonwealth Scientific and Industrial Research Organisation
Aussie GRASS	Australian Grassland and Rangeland Assessment by Spatial Simulation (project)
ENSO	El Niño Southern Oscillation
NCC	National Climate Centre
QCCA	Queensland Centre for Climate Applications
QDPI	Queensland Department of Primary Industry
SOI	Southern Oscillation Index
SARDI	South Australian Research and Development Institute
SSTs	sea-surface temperatures
SSU	(Bureau of Meteorology) Special Services Unit

6.8 References

Ash, A., P. O'Reagain, G. McKeon, and M. Stafford Smith. 2000. Managing climate variability in grazing enterprises: a case study of Dalrymple shire, north-eastern Australia *In:* Hammer, G.L., Nicholls, N., Mitchell, C. (Eds.), Applications of seasonal climate forecasting in agriculture and natural ecosystems: The Australian experience. Kluwer Academic Publishers, Dordrecht, The Netherlands, pp. 253-270.

Dudley, N.J., and A.B. Hearn. 1993. El Nino effects hurt manoi irrigated cotton growers, but they can do little to ease the pain. Agricultural Systems 42: 103-126.

Everingham, Y.L., R.C. Muchow, and R.C. Stone. 2001. Forecasting Australia sugar yields using phases of the Southern Oscillation Index. Proceedings of the International Congress on Modelling and Simulation. 1781-1786.

Everingham, Y.L., R.C. Muchow, R.C. Stone, N.G. Inman-Bamber, A. Singels, and C.N. Bezuidenhout. 2002. Enhanced risk management and decision-making capability across the sugarcane industry value chain based on seasonal climate forecasts accepted for publication. Agricultural Systems Vol 74 (3):459-477.

Hammer, G.L., D.P. Holzworth, and R. Stone. 1996. The value of skill in seasonal climate forecasting to wheat crop management in a region with high climatic variability. Australian Journal of Agricultural Research 47: 717-737.

Meinke, H., and G.L. Hammer. 1997. Forecasting regional crop production using SOI phases: an example for the Australian peanut industry. Australian Journal of Agricultural Research 48: 789-793.

Meinke, H. and Z. Hochman. 2000. Using seasonal climate forecasts to manage dryland crops in northern Australia. In: Hammer, G.L., Nicholls, N., Mitchell, C. (Eds.), Applications of seasonal climate forecasting in agriculture and natural ecosystems: The Australian experience. Kluwer Academic Publishers, Dordrecht, The Netherlands, pp. 149-165.

Power, S., W. Wright, and P. Della-Marta. (Eds), 2001 Cli-Manage 2000 (Conference on Australian climate variability) 23-25 October 2000, Albury, NSW : conference proceedings CVAP : Bureau of Meteorology. 133 p.

Singels A., and A.B. Potgieter. 1997. A technique to evaluate ENSO-based maize production strategies African Journal of Plant and Soil 14(3): 93-97.

Stafford Smith, M., R. Buxton. G. McKeon, and A. Ash. 2000. Seasonal climate forecasting and the management of rangelands: do production benefits translate into enterprise profits? *In:* Hammer, G.L., Nicholls, N., Mitchell, C. (Eds.), Applications of seasonal climate forecasting in agriculture and natural ecosystems: The Australian experience. Kluwer Academic Publishers, Dordrecht, The Netherlands, pp. 271-289

Further Reading

(Anon) 1993. Climate activities in Australia: a report on Australian participation in international scientific climate programs / prepared by the Commonwealth Bureau of Meteorology. Canberra, A.C.T. : AGPS Press, 1993.

(Anon) 2001. Life in the Tropics: Climate Science and impacts on natural ecosystems, culture, health and industry, 14th Australia New Zealand Climate Forum, Darwin, September 17-20, 2001.

(Anon) 2001. Climate and Weather Services in Agriculture, NCC. (CD-ROM)

Glantz, M. (ed.) 2001. Once burned, twice shy? United Nations University.

Hammer, G.L., N. Nicholls, and C. Mitchell (Eds). 2000. Applications of Seasonal Climate Forecasting in Agricultural and Natural EcosysteMs The Australian Experience Atmospheric and Oceanographic Sciences Library, Vol 21, Kluwer Academic Publishers, Dordrecht, ISBN 0-7923-6270-5, 469 pp.

CHAPTER 7

MANAGEMENT RESPONSES TO SEASONAL CLIMATE FORECASTS IN CROPPING SYSTEMS OF SOUTH ASIA'S SEMI-ARID TROPICS (APN 2000-017)

H. Meinke (DPI, Austalia), J. Hansen (IRI, USA), Selvaraju (Agricultural University,India)
S. Gadgil (Indian Institute of Science, India), K. Kumar (IITM, India),
M. Aslam (Pakistan Agricultural Research Council, Pakistan)

7.1 Executive Summary

South Asia is home to 40% of the Earth's poor, most of whom depend on agriculture – "the most weather-dependent of all human activities" – for sustenance and livelihood. Vulnerability to year-to-year rainfall fluctuations is particularly severe in smallholder dryland farming systems in the semi-arid regions. Previous experiences in Australia, the USA and South America have shown that the emerging capacity to forecast the likelihood of future rainfall and temperature distributions can contribute to improved agricultural productivity and farmer livelihood, underpinned by more appropriate natural resource management.

By using a systems analytical approach, this CLIMAG South Asia project has demonstrated for developing countries how cropping systems management can be altered by adapting to the underlying climatic variability. In doing so, this pilot study has built a highly effective interdisciplinary network of scientists and organisations spanning three continents (Australia, Asia and USA) that will allow effective applications of seasonal climate forecasting in the target regions.

The project officially commenced in June 2000 when contracts between START and the Department of Primary Industries (DPI), Queensland, Australia, were signed. However, much of the background work was conducted prior to that during the inaugural project team meeting, sponsored by and conducted at the IRI in NY (May 2000).

The main outcomes from this project are:

- a general process that shows how agricultural systems analysis and climate science and information can be combined with direct linkages to smallholder farmers to positively influence agricultural decisions;

- an agronomic and climatological systems analysis of cropping systems in Southern India and Northern Pakistan, including clear recommendations on where additional research efforts are needed. This includes quantification of strategic management opportunities in these cropping systems and testing of existing analytical models;

- a professional network spanning Pakistan, India, USA and Australia with the subsequent establishment of operational nodes for agricultural systems analysis in Islamabad (Pakistan), Bangalore (India) and Coimbatore (India). The approach uses participatory research methods in conjunction with agricultural simulation models and seasonal climate forecasts;

- new scientific insight into cropping systems in the target regions, including climatic conditions and processes (several scientific publications are currently in preparation);

- substantial awareness of the systems analytical approach across the Asia-Pacific region through the project's considerable input to the 'Training Institute on Climate Variability and Society in the Asia-Pacific Region', an APN sister project;

- resource material, including lectures, tutorials and software that was specifically developed for the teaching and research components of this project. Several CDs have been produced and were distributed to the participants at the Toowoomba and Hawaii workshops;

- a detailed proposal to possible funding providers for a longterm program to develop a blueprint for true ‘end-to-end’ application of seasonal climate forecasting in agricultural systems in the SAT (currently under development).

Using a participatory research approach, the project team collected baseline data for case study sites in India and in Pakistan (Fig. 7.1). Interactions with farmer groups at project sites indicated that smallholders are, from their own perspective, in a position to benefit from seasonal climate forecasts. They expressed strong enthusiasm for the project, and demonstrated sophisticated awareness of climate variability and the relevance of climate prediction for their decisions. Discussions with the farmers identified a range of relevant, climate-sensitive crop management decisions that formed the basis for subsequent analyses. Results will be discussed with these farmer groups to assess the relevance and feasibility of the findings and their likely adoption.

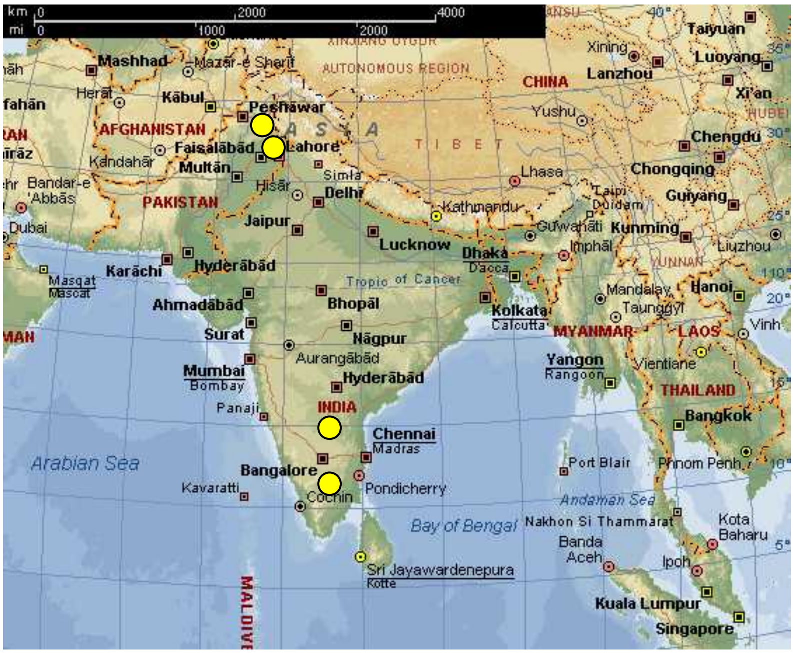

Figure 7.1 Study sites in Pakistan and India (yellow circles).

Agricultural systems analysis for northern Pakistan showed considerable potential to intensify the current wheat – fallow – wheat system by introducing grain legumes into the rotation. Under current prices and production costs, which are regulated by governmental policy, intensification appears profitable in all seasons, regardless of the forecast. However, sensitivity studies showed that a skilful seasonal forecast could become important under different cost/price scenarios. These findings demonstrate the importance of this systems analytical approach for policy decisions. It is therefore imperative for any follow-on program to fully engage the people who inform the policy process.

At the two study sites in Tamil Nadu, India, cotton and peanut crops – currently the two most profitable crops – are sensitive to rainfall shortages in different periods. The study showed considerable potential to increase mean income and to reduce production risk by tailoring farm land allocation among these crops to seasonal forecasts. The methodology developed here allows an objective comparison – on a probabilistic basis – between a range of possible options. For instance, the profitability of peanut and cotton crops differs depending on costs, prices and climatic conditions. The pilot study showed that in positive SOI years peanuts outperformed cotton in 70% years, but income difference can still range from –15,000 to +15,000 Rs/ha. However under falling SOI conditions peanuts had only a minor advantage in 40% of years (up to 3,800 Rs/ha). Such information provides an important basis for well-informed crop choice decisions.

In another example from a neighbouring region, different risk management options for peanut crops were compared. One of these risk mitigation strategies is planting density: high planting densities ensure that a high yield potential can be realised in 'good' years (high rainfall years). However, in 'poor' years such a strategy results in higher than necessary input costs (ie. seed). Simulated results indicated that peanut yield is substantially reduced in years when the SOI phase is falling in April/May. The average yield was highest in positive and rising SOI phase years irrespective of plant population levels. Financial risk can be lowered by reducing plant population by 50%. To estimate the economic consequences of reducing plant population, planting densities in the simulations were halved in years when the SOI phase was either negative or positive or falling (48 out of 99 years). For the remaining 51 years a 'standard' plant population was assumed.

Adopting the tactical approach did not result increased profit every year. However, in many years it was substantially better and in few years it was only moderately worse than the fixed management approach. Overall the tactical approach resulted in higher profits in 35% of the years, in 13% of the years the tactical approach performed worse and in 52 per cent of the years there was no difference.

All these examples demonstrate the importance of using a seasonal climate forecast within the context of real life decision making. This can only be achieved by employing a systems analytical approach that involves participatory research methods in combination with agricultural systems simulation models. The emphasis needs to be on the process of integration.

7.2 Objectives and Approaches

As part of the broader CLIMAG program, APN and START supported this multidisciplinary research project to assess the potential for seasonal climate forecasts to reduce vulnerability to climate variability in South Asia. Our approach was to develop a generic process that can be used to optimally combine knowledge and information about cropping and climate systems for better decision making in agriculture. By employing such a process, the specific objectives of this pilot study were to:

Document current predictability of relevant climate variables as a basis for understanding biological cropping system response to predictable components of climate variability.

Demonstrate via systems analysis how seasonal climate forecasts could alter management decisions to improve yields, stabilise livelihood, and enhanced sustainability of resources.

Identify other partners throughout the Asia-Pacific region, including the scientific, farmer and institutional networks necessary to ensure a successful end-to-end delivery program across national boundaries.

7.3 Design and gain additional funding for a comprehensive program

Information about climate variability and the provision of seasonal climate forecasts has the potential to reduce this vulnerability provided that it is linked to a well-structured, agricultural systems research approach. Using case studies, this project demonstrated how the potential value of such climate information to agricultural producers can be realised. Implementing these research outcomes is expected to reduce vulnerability caused by exposure to climate variability. This exploratory study constitutes a stepping stone towards a well-integrated research and delivery program that will address more comprehensively those aspects of climate risk that impede agricultural production in developing countries.

The initial project team brought together scientists and institutions from Australia, USA, India and Pakistan. Initially, the following scientists were nominated as Principal Investigators (PI):

- Dr Holger Meinke, DPI, APSRU, Toowoomba, Australia (project coordination)
- Dr James Hansen, IRI, New York, USA
- Dr R. Selvaraju, Tamil Nadu Agricultural University, Coimbatore, India
- Prof. Sulochana Gadgil, Indian Institute of Science, Bangalore, India

After project visits to Pakistan and India (September 2000, for full report see Appendix 2) it became apparent that additional regional expertise in the area of systems agronomy (Pakistan) and climate science and prediction were needed. Hence, two additional PIs were invited to join the project:

- Dr Muhammad Aslam, NARC, Islamabad, Pakistan
- Dr Krishna Kumar, Indian Institute of Tropical Meteorology, Pune, India

To achieve the projects objectives, the project team selected case study sites in India and Pakistan. At each location we had to:

- establish the capacity to conduct agricultural systems simulation;
- collect base line data (climatic, agricultural and socio-economic data) to conduct the necessary analyses;
- discuss possible management interventions with the decision makers (in this case: farmers);
- quantify the existing rainfall variability and assess the potential to forecast the seasons ahead;
- conduct the systems analyses; and
- quantify the outcome of the decisions against the status quo.

Participation in planning, conducting and reporting collaborative project research considerably enhanced technical capacity among project scientist. In particular, the training activities at APSRU in Toowoomba (Australia) and at the East-West Center in Hawaii (USA) improved the technical expertise and competence of all team members. Further capacity building was achieved through these targeted training workshops, learning and networking resulting from collaborative project activities. Mr Peter deVoil, APSRU, was specifically employed to provide software support and develop utility programs for data manipulation and teaching purposes.

As a result of the short-term funding the current project had no direct policy implications, although the Pakistan case study clearly demonstrated the importance of such links. However, the proposed follow-on program will have strong policy connections via direct interactions with Meteorological Services, Universities, extension organisations and scientists and farmer networks.

Although the research focused on the application of climate forecasting and variability information at a seasonal time scale, two general issues link it directly to global change. First, population growth and resource degradation (including urbanisation of agricultural land) are expected to increase society's vulnerability to episodic food shortages associated with climate fluctuations in the coming decades. This is particularly true for populations that depend on rainfed production, especially in the SAT. India's rainfed agricultural area is important to global food security by virtue of its size. Second, preparation for the uncertainties associated with global climate change requires an analytical framework and institutional mechanisms for anticipating and adapting to climatic fluctuations. As a CLIMAG demonstration project, the research outcomes contribute directly to the global research programs – START, IGBP, IHDP, WCRP – that sponsor CLIMAG.

7.4 Project Coordination

A series of project meetings and field visits facilitated team development and coordination of research activities. These meeting were also used as an avenue to expose the broader research community to the goals and approaches of this pilot study. Additional linkages were formed, for instance, with the participants from the APN sister project (Training Institute on Climate Variability and Society in the Asia-Pacific Region) and with Dr R. Boer, Indonesia. Dr Boer has expressed interest to be involved in follow-on activities and discussions about the development of a further APN project are continuing.

7.4.1 Inaugural Project Team Meeting, Palisades, New York, 1-2 May 2000

The International Research Institute (IRI) for Climate Prediction hosted and funded an inaugural project team meeting to (a) formulate and refine the project action plan, and (b) outline and devise a strategy for funding a more comprehensive follow-on program. Project investigators and advisors present defined a set of “building blocks” that would address the stated objectives of the APN-funded project, and serve as a foundation for an expanded project. These “building blocks” served as a basis for a detailed action plan and time line. The team identified and discussed possible synergistic activities with three complementary projects: a component of an ACIAR-funded climate prediction application project in Tamil Nadu, an ACIAR project on sorghum modelling and improvement in India, and an APN-funded training institute in Hawaii, early 2001.

Key issues related to a more comprehensive follow-up program were discussed, including identification of geographical scope, areas of expertise, scientific partners, potential donors, and institutional linkages. The follow-up program would expand the domain of the current project, integrating more thoroughly the issues of economics, policy, institutional support, communication and links to dynamic climate modelling. Reducing farmer vulnerability, and improving resilience and food security were identified as overarching issues.

7.4.2 Project site visits and team meetings, Pakistan and India, September 2000

Visits to project target locations in Pakistan (Dr Meinke) and India (Drs Meinke and Hansen) were designed to (a) provide investigators with project coordination responsibility with a better understanding of production systems, farmer networks, and collaborating institutions at each location, (b) inform and secure long-term support of farmer groups and host institutions, (c) clarify the relevant farmer decisions that would be subjected to systems analysis, and (d) collectively refine plans and responsibilities for the remainder of the project.

In his visit to Pakistan, Dr Meinke updated Dr Aslam, who joined the project team after the initial planning meeting and proposal submission, on project objectives, tasks and approaches during this visit. Endorsement of the current project and planned follow up by key national institutions – the Pakistan National Agricultural Research Centre (PARC; Dr N.I. Hashmi, Director General; Dr M. Ashraf, Director; Dr M. Aslam, Senior Scientific Officer), Pakistan Agricultural Research Council (NARC; Dr K.A. Malik, Chairman) and ASIANICS, Agro-Dev. International (Dr Amir Muhammed, Director) – also resulted from the visit.

The visit to India included a project review meeting resulting in further refinement of the work plan and an agenda for the subsequent project workshop in Toowoomba. This was followed by field visits in the case study region bordering Karnataka and Andhra Pradesh, surrounding Pavagada. Meetings and field walks conducted with two different farmer groups ("marginal farmers" and "progressive farmers") provided a clear picture of some of the key issues facing the farmers, and possible applications of seasonal forecasting under these conditions.

This was followed by meetings at Tamil Nadu Agricultural University, Coimbatore. Dr Selvaraju organized several field trips that provided a wealth of information for the scenario analyses. Based on the information gathered and the contacts made with local farmers, the project team selected as case studies two villages (Naduvacheri and Tiruchengodu) with differing climate patterns, cropping systems and infrastructure development. Important decisions, such as crop and cultivar selection in response to forecast rainfall characteristics, were identified for analysis.

Interactions with farmer groups at each project site indicate that smallholder farmers are, from their own perspective, in a position to benefit from seasonal climate forecasts. They expressed strong enthusiasm for the project, and often demonstrated sophisticated awareness of climate variability and the relevance of climate prediction for their decisions. For example, "marginal" farmers in the Pavagada region debated implications of probabilistic forecasts and prices for viability of alternatives to the dominant peanut crop. Farmers in Naduvacheri, Tamil Nadu, India, requested information about rainfall variability and its decision implications (what to plant, how to control pests and diseases) – a message that we heard consistently from the smallholder farmers. One of the farmers grows both peanut and cotton to reduce risk associated with rainfall variability. In Tiruchengodu, one farmer stressed that he understands the probabilistic nature of seasonal forecasts, and accepts responsibility for decisions based on uncertain forecasts. Our meeting host grows both bunching and runner peanut varieties as a risk management strategy due to their different timing of susceptibility to water stress.

During this trip, Dr Meinke also visited Dr R. Ruben at Wageningen University, The Netherlands, and the team of Dr N. Hamilton from the International Human Dimensions Program (IHDP) of the World Meteorological Program (WMO), Bonn, Germany. Each of those visits resulted in plans for some level of collaboration in the planned follow-up program.

7.4.3 Toowoomba Training and Analysis Workshop, 6-17 November 2000

The objectives of the workshop were to (a) familiarise team members with systems analytical tools and approaches, (b) equip participants to conduct analyses for their study regions, and (c) initiate the necessary simulations and analyses for the case studies outlined in the action plan. The first week was devoted primarily to teaching via lectures, training in the use of APSIM crop simulation tools, and identification and prioritisation of specific decision scenarios for analysis at each project site. Based on the information collected at the project sites, team members finalised input data, conducted preliminary crop simulations, and planned details of analyses including use of alternative forms of climate forecast during the second week.

Several challenges had to be addressed. Firstly, the lack of adequate, long-term climate records for simulation purposes had to be overcome. Secondly, the project team needed to become proficient in the use of the simulation platform APSIM. Often parameterisation provided a challenge due to the lack of experimental data. Training of project staff in the appropriate use of the simulation model was considerably more time consuming than initially estimated.

All the resource material, including the lecture notes have been distributed to course participants on CD.

Training Institute on Climate Variability and Society in the Asia-Pacific Region, Honolulu, Hawaii, and Final Project Meeting, February 2001

The project team presented the approach and exercises from project case studies to a group of twenty young scientists during the latter portion of the training institute led by Dr E.L. Shea (sister project; APN 2000-003). This was an opportunity to showcase results from the CLIMAG project, extend relevant skills and lessons to trainees, and discuss with a broad audience the future direction of the initial effort. Lectures, role-playing and analytical exercises were received with enthusiasm. Trainees generally felt that aspects of the approach used in this project could be adapted to other regions and sectors. A final project meeting coinciding with the Training Institute focused on strategy for completing, reporting and publishing case studies, and on design and strategy for advancing toward the more comprehensive program.

7.5 Publications Related or Arising from this Project

Results from each case study region are currently being prepared for publication in international scientific journals. We expect that his will result in at least four (and possibly more) journal articles based on chapters 4 to 7. In addition to these articles in preparation, the following publications are directly related to this project:

Hammer, G. and Meinke, H., 2000. Linking climate, agriculture, and decision-making – experiences and lessons for improving applications of climate forecasts in agriculture. Proceedings of the International Forum on Climate Prediction, Agriculture and Development. IRI-CW/00/1. International Research Institute for Climate Prediction, April 26-28, 2000, Palisades, New York, 72-76.

Hansen, J.W. 2000. IRI Strategy for agricultural applications. Proceedings of the International Forum on Climate Prediction, Agriculture and Development. IRI-CW/00/1. International Research Institute for Climate Prediction, April 26-28, 2000, Palisades, New York, 67-71.

Meinke, H. and Hammer, G., 2000. Experiences in Agricultural Applications of Climate Predictions: Australasia. Proceedings of the International Forum on Climate Prediction, Agriculture and Development. IRI-CW/00/1. International Research Institute for Climate Prediction, April 26-28, 2000, Palisades, New York, 52-58.

Meinke, H., Baethgen, W.E., Carberry, P.S., Donatelli, M., Hammer, G.L., Selvaraju, R. and Stöckle, C.O., 2001. Increasing profits and reducing risks in crop production using participatory systems simulation approaches. Ag Systems, 70: 493-513.

Meinke, H., Hammer, G., Phillips, J. and Baethgen, W., 2000. Using climate forecasts to improve global agro-ecosysteMs Book of Abstracts, 3rd International Crop Science Congress (ICSC), August 17-22, 2000, Hamburg, Germany, p. 13.

Meinke, H., Hammer, G., Power, S. and Allan, R., 2000. Multidecadal climate variability: world rainfall and impact on Australian wheat crops. Book of Abstracts, 3rd International Crop Science Congress (ICSC), August 17-22, 2000, Hamburg, Germany, p. 43.

Meinke, H., Hammer, G.L. and Selvaraju, R., 2000. Using Seasonal Climate Forecasts in Agriculture - The Australian Experience. 'Proof of Concept' or 'Taking The Next Step: Concept Adaptation'? In: Sivakumar, M.V.K. (ed.), Climate prediction and agriculture. Proceedings of the START/WMO International Workshop, Geneva, Switzerland, 27-29 September 1999. Washington DC, USA, International START Secretariat, p. 195-213.

Meinke, H., Pollock, K., Hammer, G.L., Wang, E., Stone, R.C., Potgieter, A. and Howden, M., 2001. Understanding climate variability to improve agricultural decision making. Tenths Australian Agronomy Conference. Australian Society of Agronomy (eds.), 2001, Hobart, Australia.

Meinke, H., Aslam, M., Gadgil, G., Hammer, G.L., Hansen, J., Krishna Kumar, K. and Selvaraju, R., 2001. Towards resilient farming systeMs 2nd International Symposium – Modelling Cropping Systems, July 16-18, 2001, Florence, Italy.

Meinke, H., Aslam, M., Gadgil, G., Hansen, J., Krishna Kumar, K. and Selvaraju, R., 2001. Agricultural systems, climate and the human dimension: 'hard data for soft systems'. The 2001 Open Meeting of the Human Dimensions of Global Environmental Change Research, October 6-8, 2001, Rio de Janiero, Brazil.

Selvaraju, R., Meinke, H., Aslam, M., Gadgil, G., Hansen, J. and Krishna Kumar, K., 2001. Management responses to climate variability and change in cropping systems of South Asia. Global Change Open Science Conference July 10-13, 2001, Amsterdam, The Netherlands.

7.6 Climate Variability and Seasonal Climate Forecasts

As part of this one-year pilot study we did not attempt to develop, test or implement new or improved forecasting schemes for this region. Instead the project team agreed to use the best available current information based on ENSO to demonstrate the potential of such information in on-farm decision making. However, the consistency of the ENSO signal in terms of its impact on the monsoon has recently been questioned and it is therefore important to look towards scientific advances in our understanding of climate variability in this region. Hence, we took a two-tier approach to seasonal climate forecasting as part of this pilot study: In the first instance we used SOI phases based on the research by Stone et al., 1996 (Prediction of global rainfall probabilities using phases of the Southern Oscillation Index. Nature 384, 252-55) as an example of our current ability of seasonal climate forecasting in this region. As a second step, Dr K. Kumar conducted a detailed regional analysis of rainfall, including suggestions on how to advance seasonal forecasting for this region in the future.

7.6.1 General description of climatic features and issues for the future

South Asia, where our target countries of India and Pakistan are situated, is dominated physically, culturally and economically by the most important monsoon systems of the world. The southwest or summer monsoon is the principal source of water for most of the country, the northeast or winter monsoon is particularly important for the southern peninsular regions of India. The whole year's supply of water over a major part of the area is realised in just 3 to 4 months in the summer monsoon season, which makes the people critically dependent on the monsoon activity. The rainfall over these two countries is subject to a high degree of spatial and temporal variability, leading to a variety of climatic zones, ranging from arid to moist tropical rain-forest, and the occurrence of devastating droughts and floods. The striking regional contrasts in rainfall can be understood from Cherrapunji's (Northeast India) annual average of 10.8 m (the world's highest, with a record of 24.0 m) to almost rainless years in Sind (Pakistan). Apart from these large spatial variations, the year-to-year variability of monsoon rainfall in these countries occasionally leads to large scale floods and droughts over different parts resulting in serious reduction in agricultural output affecting the regional and national economies. In view of the critical influence of such variability on agricultural and industrial production, forecasting of monsoon rainfall, at least a season in advance, assumes profound importance for policy making and planning mitigatory efforts.

The mechanisms responsible for inter-annual variability of seasonal mean climate can be thought of as a consequence of internal dynamics and boundary forcing. There is considerable evidence that the internal dynamics, which are a manifestation of non-linear chaotic dynamics of the atmosphere, is relatively weak in the tropics. It is also generally known that the inter-annual variability in the summer monsoon rainfall is largely determined by the slowly varying boundary forcing factors such as sea surface temperature, sea ice cover, land surface temperature, albedo, soil moisture and snow cover, although not all of them are equally important. Variations in lower boundary conditions result from the coupling of the dynamics of the atmosphere to the dynamics of the oceans and to the hydrology of the land masses. The most dominant mode of variability of the tropical ocean-atmosphere system associated with El Niño/Southern Oscillation (ENSO) has its origin in the tropical Pacific and extends to influence much of the globe. ENSO accounts for a significant part of variability in the Indian summer monsoon rainfall.

Apart from ENSO, the areal extent and thickness of Eurasian/Himalayan snow in preceding winter and spring seasons is also known to have a profound influence on the strength of ensuing monsoon, via enhancement or reduction of the land-sea thermal gradient. This suggests considerable potential predictability of the inter-annual variability of the monsoon system on seasonal time scales. However, significant inter-decadal changes occur in the strength of relationship between monsoon rainfall and various precursors/predictors. Of particular interest and relevance to the target region is the recent weakening of monsoon-ENSO relationship attributed generally to (1) a southeast-ward shift in the ENSO induced anomalous Walker circulation leading to reduced suppression of convection over the Indian sub-continent, thus favouring normal monsoon conditions, and (2) increased surface temperatures over Eurasia in winter and spring as a consequence of recent mid-latitude continental warming trend, resulting in enhanced land-ocean thermal gradient conducive for a strong monsoon.

Diagnostic studies, involving both regional and global meteorological data sets, carried out to identify precursors of seasonal rainfall on an all-India scale and also at individual project sites, indicate that the reduction in predictive skill due to the weakening monsoon-ENSO links in recent decades appears to be compensated to a large extent by the increased role of Eurasian winter surface temperatures (taken as a proxy for snow conditions) and sea surface temperatures over the north Indian Ocean. These provide apparent predictability at long (6 to 9 months prior to the monsoon season) lead times. Several experiments using Max-Planck Institute's (MPI) atmospheric general circulation model (AGCM) have been conducted to study the sensitivity of monsoon rainfall over the Indian sub-continent to different El Niño related sea surface temperature patterns over the Indo-Pacific basins, with and with out continental warming. These experiments corroborate the general role of recent Eurasian continental warming in counteracting the negative impacts of El Niño events on monsoon rainfall. Based on these diagnostic studies, prediction schemes (empirical at this stage) have been developed following a step-wise regression algorithm by initially screening more than 40 different precursors covering various facets of ocean-land-atmosphere system for all the target stations of the present project. For reasons discussed above, predictors representing the ENSO conditions (both sea surface temperature and sea level pressure indices) prior to monsoon season; winter Eurasian surface air temperature; previous summer and autumn sea surface temperatures over the north Indian Ocean (particularly Arabian Sea) and those indicating the pre-monsoon thermal conditions over the Indian region have been included in the prediction schemes. The prediction schemes, in general, yielded respectable skills in both hindcast and independent modes of verification for most of the target stations.

Time constraints restricted us to develop seasonal forecast schemes using only empirical methods. For the expanded project, we propose to develop statistically- or dynamically-downscaled seasonal climate forecast products from general circulation model projections for the target regions in order to provide forecasts at spatial and temporal resolutions appropriate for agricultural decision making. Detailed climate characterization and description of prediction schemes at all the sites of the project will be included in the Final Project Report.

Climatically, a large part of Pakistan is arid to semi-arid, with large spatial and temporal variability in many climatic parameters. The orographic features of Pakistan have a great influence on its climate, and there are peculiarities resulting from its geographical location. The western fringes of active monsoon disturbances during the southwest monsoon season contribute considerably to the rainfall over the eastern plains (the target sites are located here), while the western disturbances and other circulation systems, mostly active in the winter and in the transition period of the pre-monsoon, are the main source of precipitation over the western parts. The target sites in Pakistan receive nearly 70% of their annual rainfall in summer monsoon season.

7.6.2 Current skill of seasonal forecasting based on SOI phases

Significant, physically based lag-relationships exist between the Southern Oscillation Index (SOI) - an index of the El Niño/Southern Oscillation (ENSO) - and future rainfall amount and temporal distribution in eastern Australia and many other areas across the globe (Stone et al., 1996). An El Niño event, which generally corresponds to negative Southern Oscillation Index (SOI) values, usually lasts for about one year, beginning its cycle in the austral autumn period of one year and terminating in the autumn period of the following year. During the termination of an El Niño event the SOI may rise sharply. Stone et al. (1996) have shown how phases of the SOI are related to rainfall variability and are useful for rainfall forecasting for a range of locations in Australia and around the world. As the SOI pattern tends to be 'phase-locked' into the annual cycle (from autumn to autumn), the SOI phase analysis provides skill in assessing future rainfall probabilities for the season ahead.

We have employed this system and showed skill in forecasting rainfall distributions for sub-divisions of Indian rainfall districts. Figure 7.2 illustrates the different effects ENSO has on the peak rainfall seasons in Sub-Himalayan West Bengal (June to September, Fig. 7.2 left) and the Tamil Nadu region (September to December, Fig. 7.2 right). The diagram shows the probability of exceeding a certain rainfall amount for each of the 5 SOI phases. The analysis clearly shows the contrasting effects of ENSO on these two different regions: In West Bengal a consistently positive SOI phase (often associated with La Niña conditions) preceding the rainy season (JJAS) results in higher rainfall probabilities, particularly when compared to a consistently negative SOI phase (often associated with El Niño conditions). The reverse is evident in Tamil Nadu for the SOND rainfall period.

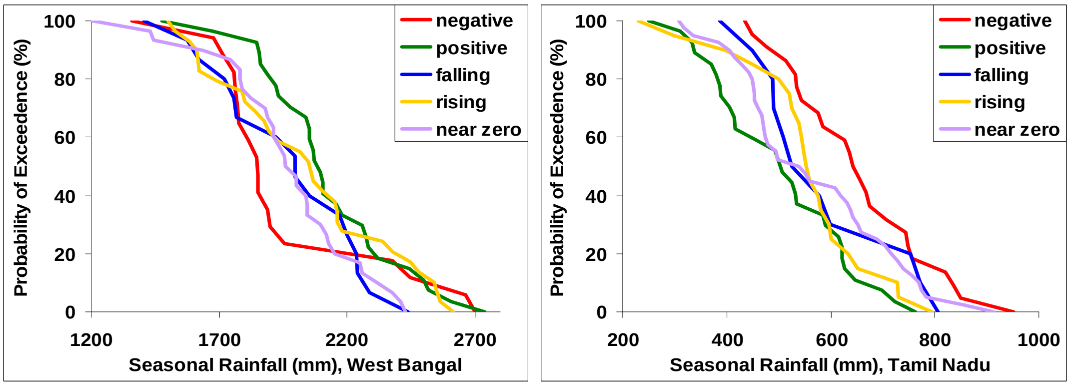

Figure 7.2 Probability of exceedence of JJAS rainfall for Sub-Himalayan West Bengal Region based on April/May SOI phases (left) and SOND rainfall for Tamil Nadu based on July/August SOI phases (right). The phases are classified as consistently negative, consistently positive, rapidly falling, rapidly rising and near zero.

7.6.3 Tamil Nadu

This region frequently experiences problems due to erratic monsoon seasons, crop failures and often inappropriate resource management. The variability even within the sub-division

(Fig. 7.2, right) is high and ENSO effects differ markedly depending on the distance from the Western Guards. In the main cropping regions there is a stronger ENSO signal during the Northeast monsoon (Table 7.1). In both seasons variability is less in negative SOI phases with chances of getting at least median rainfall considerably higher than in other years.

Table 7.1 Probability of exceeding the long-term median rainfall during either the south-west monsoon (SWM) or the north-east monsoon (NEM) in relation to the five SOI phases preceding these seasons.

SOI Phase	*SWM (%)*	*NEM (%)*
Negative	80	75
Positive	55	47
Falling	42	46
Rising	35	30
Near Zero	30	58

7.7 Case Study Pakistan

For Pakistan two sites were selected as a case study for the CLIMAG demonstration project (Figure 7.3). The aim was to explore the productivity of the given cropping system and to make more effective management decisions through systems analysis, seasonal climate forecasting and climate variability information. For both locations we collected data on current cropping systems, key decision points faced by farmers, soil, climate and socio-economic circumstances. These results were summarised in two comprehensive reports and presented at the Toowoomba workshop held during November 2000.

Figure 7.3 Map of study region, Pakistan.

7.7.1 Islamabad Zone

Agricultural production around Islamabad is based on dryland cropping and hence wholly dependent on either in-season rainfall or stored soil moisture. It centres on the Pothwar Plateau comprising 6 districts. The Pothwar Plateau has three distinct rainfall zones ie. high (>750 mm), medium (500 to 750 mm) and low annual rainfall (<500 mm). During winter (Rabi season), wheat, the staple food, is sown on 90% of the area. Cropping intensity tends to be relatively low with large areas left fallow for a whole year to conserve soil moisture. While this appears to be a sensible risk mitigation strategy under low rainfall conditions, there may be scope for intensification of this productions system. We therefore addressed these questions:

- Are there opportunities to increase cropping intensity particularly in high to medium rainfall areas?
- Can mungbean be introduced as an opportunity crop to increase fallow water use efficiency?
- What are the likely consequences of a mungbean crop for the subsequent wheat crop in terms of yield and production stability?

7.7.2 Use and parameterisation of the APSIM model

To answer these questions, the cropping systems simulation model APSIM was parameterised and tested for Islamabad zone using local data of soil, climate and crop management for wheat and mungbean crops. For this purpose experiments conducted at NARC, Islamabad, from 1992 to 1994 were used to test the model's performance. This showed that the model was capable of reproducing realistic mungbean and wheat yields under a range of climatic and soil moisture conditions. This allowed us to use the model analytically to investigate the effect of mungbean opportunity cropping against the background of local climate variability. Using 30 years of historical daily weather data (1961 to 1990) APSIM simulations were perform for wheat and mungbean crops separately and then for a mungbean – wheat rotation. A soil with a plant available soil water holding capacity of 280mm was assumed for the preliminary results presented here. Simulated yields were used to calculate gross margins for both the traditional wheat – fallow – wheat systems and for mungbean as an opportunity crop within a wheat dominated cropping system. An SOI-based forecasting system (SOI phases, Stone et al., 1996, Nature 384: 252-55; see also chapter 4) shows some skill in predicting future rainfall distributions for both the Kharif and Rabi seasons in this region. This allowed an assessment of the potential value of seasonal forecasting for cropping decisions.

7.7.3 Results

For the gross margin (GM) analyses, current prices and production costs were assumed. For mungbean (wheat) the prices were 12 (10) Rs/kg and production costs 1200 (4500) Rs/ha. Fig. 7.4 shows the probability of exceedence for the annual difference between the mungbean – wheat rotation and the wheat monoculture. A negative difference indicates that for the year in question the wheat monoculture would have resulted in a higher GM; conversely a positive difference indicates advantage of the mungbean – wheat rotation over the wheat monoculture that year. Under the given costs and prices, location and soil type, the results show that a mungbean – wheat rotation would have be advantageous in 86% of years (Figure 7.4, left).

When these results were stratified by May/June SOI phases, we found that when the SOI phase was either negative or falling – a pattern frequently associated with El Niño conditions – 80% of all years resulted in advantages from the mungbean – wheat rotation with an average advantage of 6322 Rs/ha (Fig. 7.4, right). When the SOI phase was either positive or rising in May/June (typical for La Niña conditions), 90% of years favoured the rotation and the average advantage nearly doubled to 10616 Rs/ha. All seven years when the SOI was in a 'near zero' phase resulted in an advantage for the mungbean – wheat rotation (average = 11819 Rs/ha).

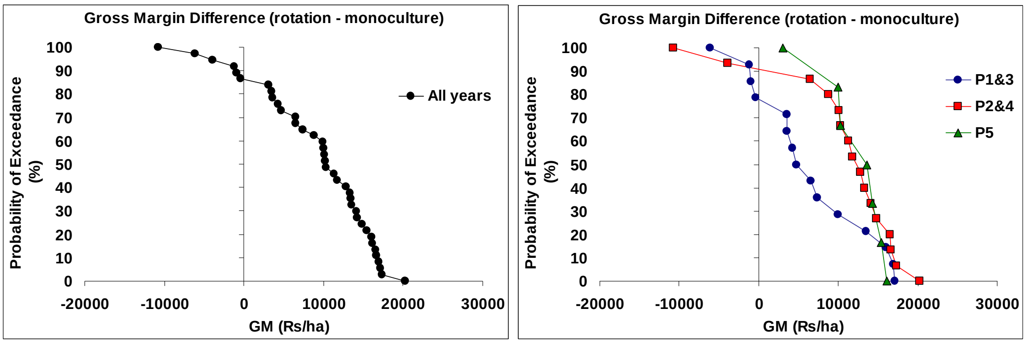

Figure 7.4 Probability of exceeding annual difference of GM between the wheat monoculture (traditional system) or the mungbean - wheat rotation. A negative outcome indicates advantages of the monoculture, a positve outcome advantages of the mungbean – wheat rotation. The diagram on the left shows the results regardless of seaonal outlook (all years), on the right these years were split into 3 categories based on the May/June SOI phase (known prior to sowing).

Based on this preliminary analysis, the introduction of mungbean into the wheat - fallow-wheat system appears economically beneficial in most years, regardless of the SOI-based seasonal forecast. Advantages were considerably lower in years when the May/June SOI was either negative or falling. A changed cost / price structure or a different soil water holding capacity could significantly change these findings. In a region where commodity prices and input costs are regulated, this type of analysis could become a powerful tool to assess the likely effect of policy intervention. These results are currently being discussed with farmers in the region. Some small scale experimental planting of mungbean is expected for the next seasons.

7.7.4 Lahore Zone

In this region, rice is the dominant summer crop (Kharif season, 74% of area sown) and wheat is the dominant winter crop (Rabi season, 77% of area sown). Currently, the dominant cropping system is rice - wheat with 94% of the farmers follow this cropping system. Wheat should be planted as soon as possible after the harvest of the rice crop to ensure a high yield potential. This yield potential is estimated to be reduced by 1% with every day sowing is delayed after 20 November. Changing surface management practices from conventional tillage to zero tillage considerably reduces the time needed before wheat can be planted. However, it also requires better weed management practices and chemical weed control. Hence, APSIM-Wheat is used to assess and quantify the possible advantages of zero tillage. The model was tested using local data from on-farm experiments conducted on zero tillage and conventional system by PARC's Wheat Program from 1984 to 1990. The model predicted the experimental results well. Long term simulations were performed using climatic data from 1961 to 1999. Although results are still being analysed, preliminary findings indicate that based on October/November SOI phases the conventional system is more vulnerable to the climatic variability than the zero tillage system.

7.8 Case Study Tamil Nadu, India

7.8.1 Background

About 70% of the population in Southern Indian state of Tamil Nadu depends on agriculture for their livelihood. The vulnerability of rainfed production systems to climate variability is enhanced by the high water use of nearby intensively irrigated cropping systems. The mean annual rainfall in the study region is 640 mm, while the mean annual potential evaporation is 1620 mm indicating typical semi-arid conditions. The region consists of mainly red (Alfisols) and black (vertisols) soils. The red soils are shallow with low water retention capacity and the black soils are moderately deep with water stagnation during heavy rains and cracking during droughts. Both the soils are low in major nutrients combined with climate related constraints.

Peanut, cotton and sorghum are the principal dryland crops of this region, with most of the crops produced during the summer (June-September) and winter (October-December) monsoon seasons. The major cropping systems in the rainfed regions are peanut - sorghum, peanut – pulses, cotton – fallow on the red soils and cotton – fallow, pulses – sorghum, cotton/sorghum/chickpea (response system based on rainfall) on the black soils. These systems evolved decades ago for several economic and subsistence farming reasons. A skilful forecasting system can potentially reduce the risk during bad years and utilise the opportunities in good years.

To evaluate the likely performance of alternative crops such as peanut, cotton and sorghum we used the cropping systems model APSIM in conjunction with long-term, daily weather records. The model requires daily meteorological data as inputs. Two locations, namely Avinashi and Thiruchengodu, were considered (Fig. 7.5). Long-term daily meteorological data were available from 1901 to 1999 for both the places. The model was parametrised using the observed soil physical and chemical parameters. Soils for both locations are characterised as shallow Alfisol. The bunch type peanut variety (TMV-2), medium duration dryland cotton (LRA5166) and a tall growing sorghum variety (M35-1) were used for the simulations in accordance with local practise.

Figure 7.5 Location of Indian study sites, indicated by yellow circles. The two sites in Tamil Nadu, near Coimbatore are Avinashi (west) and Thiruchengodu (east).

7.8.2 Farm surveys

Farm surveys were conducted at the selected case study locations (Avinashi and Thiruchengodu), which are both dominated by red soils with groundnut based cropping systeMs Thirty farmers, randomly selected from the two locations, were surveyed for description of the physical environment, socio-economic environment, agricultural systems and cropping systeMs The category of the farmers included for the survey are marginal farmers (<1 ha), small farmers (1-2 ha), semi-medium farmers (2 – 4 ha), medium farmers (4-10 ha) and large farmers (>10 ha).

Focus group meetings were conducted at two case study locations (Avinashi and Thiruchengodu) to identify the cropping system determinants and to develop effective educational programs to communicate the seasonal climate forecasts. The primary aim also included identification of the major decision rules used by farmers (e.g. sowing rain, sowing window, harvesting time, initial soil moisture). Farmers' selection was based on previous interaction with the State Department of Agriculture extension officers and farmers in the region. These dryland producers were asked to discuss observed changes in the cropping systems over the years and provide possible reasons for the change. The farmers were also asked to discuss the most important factors affecting their decision and to identify the leverage points where seasonal forecasts could influence decisions. The most important issues identified through survey and focus group meetings were crop choice, plant population (seeding rate), nitrogen management, commodity prices and input costs.

7.8.3 Avinashi

The long term annual average rainfall of the region is 718 mm. This region is dominated by the winter monsoon rainfall between October and December. Farmers are sowing either peanut or cotton during the summer monsoon season (June-September). If cotton is planted, the crop overlaps into the subsequent winter monsoon season as well. If peanut is sown, short duration pulses or sorghum follow. The sowing decision for both peanut and cotton are based on the receipt of 20 mm of rainfall in 4 consecutive days. The sowing window for peanut is June 1-July 31. The question remains: which is the more profitable crop in any given season?

Results show that the chance of achieving at least 1000 kg of peanut yield / ha when the SOI phase is positive for April/May is 65%. Conversely, there is only 32% chance of achieving such a yield in years when the SOI phase is falling. Similar analyses were conducted for cotton and the economic performance of both systems was compared on a gross margin basis (Fig. 7.6). Results are presented as the probability of exceeding annual difference in gross margin (peanut – cotton). It clearly shows that in positive SOI years peanuts outperformed cotton in 70% years, but income difference can still range from –15,000 to +15,000 Rs / ha. However under falling SOI conditions peanuts only had an minor advantage in 40% of years (up to 3,800 Rs / ha). Consequences of such crop choices based on seasonal forecasts for the following rotations have also been evaluated and will be presented in the final report.

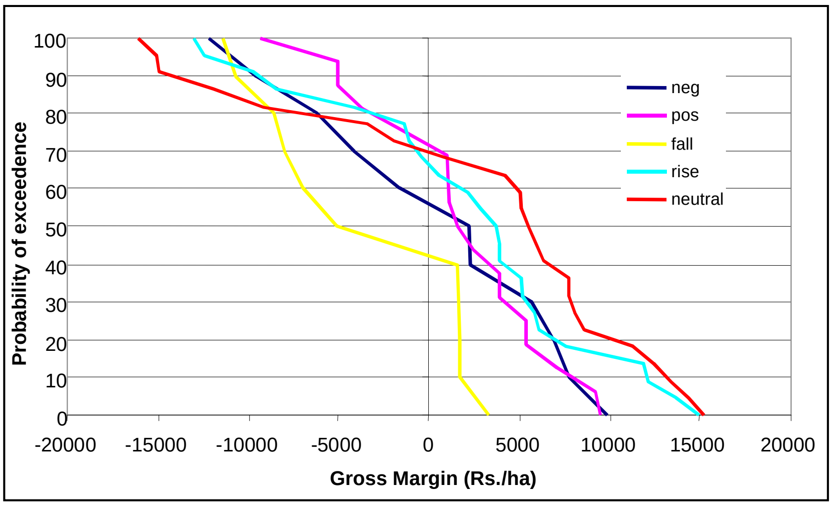

Figure 7.6 Cumulative probability of difference in gross margin (GM) for various SOI phases (positive difference indicate the advantage of peanut over cotton)

7.8.4 Thiruchengodu

This region is dominated by both summer and winter monsoon seasons with an annual longterm average rainfall of 789 mm. Farmers are growing peanut during the summer monsoon season, followed by sorghum. Both peanut and sorghum have dominant places in the system without any other crop choices under rainfed conditions. Sowing decision for peanut is any rainfall event of >25 mm in 4 days between June 1 and August 10.

Comparing the simulated peanut yields over the 99-year record showed that the peanut yield is substantially reduced in years when the SOI phase is falling in April/May (Table 7.2). The average yield was highest in positive and rising phase years irrespective of plant population levels. Financial risk can be lowered by reducing plant population by 50%. The main consideration for reduced population is to minimise the cost of seed, which accounts for almost 40% of the total cost of cultivation.

Table 7.2 Mean yield, median yield and standard deviation of simulated peanut yield (kg/ha) for two plant population by SOI phases at Thiruchengodu, Tamil Nadu, India.

SOI phases	**Higher plant population (30 plants/m^2)**			**Reduced plant population (15 plants/m^2)**		
	Mean	*Median*	*SD*	*Mean*	*Median*	*SD*
Negative	1828	1865	532	1836	1913	443
Positive	2058	2111	452	2046	2166	409
Falling	1625	1516	733	1617	1629	647
Rising	2061	1922	539	2048	2026	434
Neutral	1845	1922	547	1819	1893	524
All	1917	1922	559	1904	1959	497

To estimate the economic consequences of reducing plant population, the planting density was halved in years when the SOI phase was either negative or positive or falling (48 out of 99 years). For the remaining 51 years a 'standard' plant population was assumed. The average increase found for the tactical approach is derived from a distribution of differences between the two approaches (using or not using the forecast information) on a year-by-year basis. Adopting the tactical approach did not result increased profit every year. However, in many years it was substantially better and in few years it was only moderately worse (Fig. 7.7). Overall the tactical approach resulted in higher profits in 35% of the years, in 13% of the years the tactical approach performed worse and in 52 per cent of the years there was no difference.

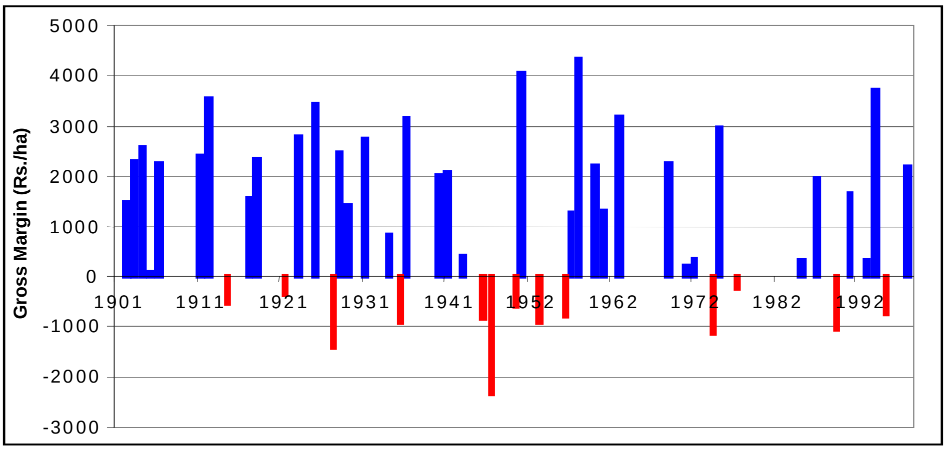

Figure 7.7 Difference in gross margin between tactical (forecast responsive) and fixed (non-responsive) plant population management for rainfed peanut at Thiruchengodu.

7.9 Case Study Bangalore, India

7.9.1 Socio economic environment

7.9.1.1 Social structure land holding distribution

The study area is in Pavgada taluk (near Ananthapur, Fig. 7.5). Here the habitations are mostly villages and hamlets. Villages typically consist of about 300 households belonging to different endogamous groups (castes). Hamlets are much smaller in size consisting of about 60 households all of them often belonging to the same caste group. For all caste groups, peanut is an important crop. Large farmers (land holding of > 12 ha) generally own lands with soils that are relatively deep, fertile and often located next to the village. These farmers belong to high and medium social status caste groups. Small and marginal farmers (with land holdings of 2 - 12 ha and < 2ha, respectively) usually belong to low and middle status caste groups, characterized by shallow soils with low fertility, located further away in the upper parts of the watershed. In the region, more than half the peanut farmers are marginal farmers and a considerable number are small farmers. In Pavgada taluk (about 1350 km^2) 54% are marginal farmers (with about 36% of the land holding), 39% small farmers (with about 49% of the land holding) and only 7% are large farmers (with about 14% of the land holding).

The changes that led to the evolution of the current cropping system also led to the transformation of the structure of the farming community. Prior to the sixties, almost all of the rain-fed lands belonged to the large farmers. The cultivation on these lands was done by share croppers. At that time, a large fraction of the land was also under natural vegetation, which supported livestock and a large number of people who depended on the livestock. In addition, there were people with specialised skills such as tanning of leather, manufacturing cloth using handlooms and dyeing of cloth. From the early sixties, land reform legislation led to major changes in land-holdings and a large number of share croppers became marginal / small farmers. Also, much of the land under natural vegetation was cleared for agriculture and the erstwhile cowherds and shepherds also became small / marginal farmers. With development of roads and competition from the large factories in the towns, the local production of leather and textiles became unprofitable and those skilled in these crafts also took to agriculture. Thus the diversity of occupations decreased markedly and a farming community with large disparities in land-holding and resources, cultivating mainly peanut on their rainfed lands, was created.

It is important to note that although there is considerable disparity in the land-holding and availability of resources, there is hardly any difference in the know-how of the different types of farmers. There is considerable rapport between the different types of farmers in the same locality. The large farmers often seek advice of the marginal farmers before making decisions about the timing of ploughing, sowing etc.

7.9.1.2 Farm economics

The yield of rainfed peanut varies considerably from year to year, largely in accordance with associated rainfall variability. In the best year (1998) the highest yield obtained by the marginal farmers is about 1.1 t/ha. The yields of large farmers are much higher, presumably due to higher use of fertilisers and other inputs. The typical cost of cultivation is Rs 6000 per ha and market price for peanut is Rs 12,000 per t. This implies that for yields below 0.5 t/ha the cost of cultivation exceeds the income. In 1997, the yields were below this level in many of the cases. It is intriguing that despite such low yields in some years, farmers continue to grow peanuts in the rainfed areas. The commonly held view is that no better options are available. Further, the perception of what is reasonable or economical is interesting. Marginal farmers use largely family labour and do not count it as component of the cost of cultivation. Hence they have a somewhat biased perception of profits. For example, typically 50% of the contribution for labour + bullock (ie. about the equivalent of 0.17 t/ha) is discounted in their investment and hence a yield below 0.33 t/ha (instead of 0.5t/ha) is considered as a crop failure.

Whereas marginal farmers do not take into account family labour, large farmers also underestimate the cost of farming operations by not taking into account maintenance of tractors and other machinery. Peanut prices fluctuate strongly and it is questionable whether on time-scales of 10 years or more peanut production is indeed economically viable. Hence, alternative crops need to be considered urgently.

7.9.1.3 Access to credit

For many large farmers and some of the small farmers' money lending and trade are important additional sources of income. The annual interest rates for loans range from 24 to 60%. However high percentage of recovery is dependent on good yield of peanut – the only crop for which credit is readily available. Trade by large farmers often involves marketing decisions. They purchases commodities at low market prices during harvest (mostly peanut) and sell them when prices improve. Many of the large and small farmers are actively involved in politics. For them a significant fraction of income is derived from execution of government contracts, subsidies, and other government programs. Generally, however, the contributions from off-farm employment to the family income is rather small.

7.9.1.4 Vulnerability and coping strategies

Marginal farmers have several strategies to cope with low yields. In case of a moderately low yield, the marginal farmers sell the manure (FYM), peanut seeds, peanut haulm as fodder and if necessary, livestock. If the yield is extremely low or moderately low in two or three consecutive years, they have to resort to what they consider extreme measures for survival. These involve leasing out the land and adults in the family move to other regions seeking employment. Although government-sponsored drought relief programs exist, farmers often need to borrow more money from the local money lenders in such years. These farmers seem to be almost continuously in a debt trap. If they do not have seeds (as it often happens in a year following one with low yield), they take these from the money-lenders for sowing and have to return 150% after harvest. The interest charged for money borrowed from these local money-lenders is also high. However, they prefer the local money lenders to the banks since they are more responsive to the needs and give the loan whenever needed. In fact, most of these farmers avoid the bank because many of them have defaulted before.

The small farmers borrow money from money lenders as well as banks in years of low yield. They also sell cattle, sheep, goat, farm trees and crop lands. In the year following one with poor yields they reduce the fraction of peanut in intercropping. The large farmers borrow money from banks and sell farm trees and also land, if necessary. Prior to 1997 large increase in price of peanut during off season were common. This generated large profit for farmers involved in trade. Recently, changes in import/export policies and lowering import duties has caused changes in the pattern of domestic price fluctuations of peanut and other important commodities of trade in the region.

Most of the large farmers are engaged in money lending business to some extent though only some of them operate on a large scale. In this business no formal records or legal agreements are involved and the recovery of the loans depend on mutual trust and social pressure. In recent years, the influence of leftist-radical revolutionaries has extended to several parts of study area. Under the rapid spread of this movement, money lenders are often targeted for extortion. There is also a steady erosion of social values on which recovery of the loans given by money lenders depends.

7.9.2 Simulation of peanut yield and biomass with APSIM

For this region a systems simulation capability is required in order to evaluate possible alternatives to peanut. This requires detailed model parameterisation, including access to experimental data. This is a time consuming process that cannot be achieved within the time frame of a one-year pilot study. The modelling framework APSIM contains crop modules for most of the key crops (eg. peanut, pigeonpea and other legumes). Preliminary results indicate that APSIM can simulate climate induced variability of biomass and yield of rainfed peanuts (TMV-2 variety) for the study region near Anantapur. Parameterisation provided a challenge, because genetic coefficients for TMV-2 (a short duration Virginia bunch variety) were not readily available. During the Toowoomba workshop, the APSIM team suggested the appropriate cultivar parameters for this variety. Simulation from 1970-98 show that APSIM is, with a couple of exceptions such as 1985 and 1987) able to capture the year to year variations in both biomass and yield. However, possible cultivar difference as suggested by local farmers can only be simulated once the necessary experimental data to derive the necessary parameter values have been conducted and analysed. Work is now under way to parameterise alternative crops so that comparisons similar to those conducted for Pakistan and Tamil Nadu can be conducted.

7.10 Lessons Learned and Recommendations – The Next Phase

Based on the encouraging results of this feasibility study we propose the funding and implementation of a larger network that comprehensively addresses all the components outlined in Fig. 8.1 (see below). The CLIMAG South Asia project team believes to have clearly demonstrated that via a systems analytical approach effective networks can be put in place that can considerable reduce climate related vulnerability in agricultural systems Once implemented, such an interdisciplinary network would be self sustaining by (i) attracting systems thinkers across the disciplines and (ii) through the provision of objective methodologies for decision making at farm, marketing or policy level. The emphasis will be on relevant knowledge acquisition and dissemination with a clear intention to intervene in order to achieve better outcomes. It will provide objective tools that allow the assessment of the economic, social and environmental consequences of alternative decisions.

The RES AGRICOLA network will take a large step beyond climate impact assessments by evaluating and quantifying potential short, medium and long term adaptive responses within farming systems. It will draw on the collective expertise of the global research community to develop ‘resilient’ cropping systems

Climate variability generates risks for decision-making on both short and long time horizons because outcomes of decisions cannot be predicted with certainty, be they farm enterprise related decisions (e.g. crop choice, stocking rate, water allocation, or insect population management) or policy related decisions (e.g. access to credit, price policy or subsidies). Risk, or the chance of making a financial or environmental loss, is a key factor pervading decision-making in management of agricultural and natural ecosystems. A systems approach in a problem-solving context requires on-going connections between decision-makers, advisors, modellers and researchers for effective outcomes. This integration of skills is required to achieve the balance needed between practicalities of system management, needs of decision-makers, and development and use of system simulation or expert knowledge to evaluate options.

So far, the CLIMAG South Asia team has been successful in attracting some funds from START and NOAA (OGP) to keep exisiting activities and relationships alive and to progress the overall RES AGRICOLA development. Several project proposals that could come under the RES AGRICOLA initiative have already been submitted to various funding agencies. The following section outlines in more details the philosophy and approach of RES AGRICOLA.

7.11 Climate and Agriculture: From Vulnerable to Resilient Farming Systems

RES AGRICOLA *(Latin: Farmer's business)*
A CLIMAG initiative

Concept to establish an international, interdisciplinary network that will quantify and implement adaptive responses to climate information within the world's farming systems

RES AGRICOLA - a network for farmers, scientists, policy advisers, extension specialists and other stakeholders concerned with connecting climate, agricultural science and decision making.

7.11.1 Climate variability and change poses risks and opportunities for farmers

In developing countries climatic factors are a major source of vulnerability for a large proportion of the rural population. Based on the success of the CLIMAG South Asia pilot study, we propose the establishment of an interdisciplinary network that will draw on the collective expertise of the global research community to develop 'resilient' farming systeMs These are systems that are to a large extent 'climate proof' by allowing farmers to draw on systems resources (e.g. water, nutrients, reserves) at times of need, with these 'debts' being repaid once climatic conditions improve. The network, to be known as RES AGRICOLA and run under the hospice of START's CLIMAG program, will develop resilient farming systems that are in tune with current climatic conditions and adaptable to climate variability and change. This network will eventually become self-sustaining through the valued provision of objective methodologies for decision making at farm, marketing and policy level and by attracting systems thinkers across the disciplines.

Adaptive responses to climate information or climate forecasts can be instigated either directly by the farm manager in response to an anticipated future or indirectly via changed policy conditions to which the farmer will respond inherently. Although RES AGRICOLA's target is to influence farmer behaviour and ultimately increase farm resilience, the decision-maker might be either a farmer or a policy maker. Farmers are encouraged to adapt management in a way that is technically, socially, economically, and environmentally feasible, while policy makers are encouraged to modify policy instruments that will drive such a feasible farmer response. A major part of this network will be determining which of these pathways (or what level of combination) will result in the desired outcomes.

As a global community, we know much about climate, agriculture and socio-economic systems and approaches. RES AGRICOLA is about connecting our component knowledge across disciplinary boundaries to create knowledge and wisdom systems for the benefit of all rural communities.

RES AGRICOLA will deliver a general methodology/process for reducing vulnerability of farming systems operating under climatic risk.

The process will be applicable globally and builds largely on approaches that have proven successful in developed AND developing countries. A recently completed pilot study in resource poor systems of South Asia showed that climate information and climate forecasting can also be value added via systems analytical, participatory research approach. RES AGRICOLA will cover the dimensions of climate science and information, agricultural systems, and socio-economic systems with a focus on farmers in risky environments, be they in resource poor or resource rich systems It will provide a means to reduce vulnerability caused by exposure to climate variability at the field, farm household and village level. Analysis of policy options, constraints and their feedbacks on farm management will form an important part of this research network.

A participatory research approach that includes all players will link individual partners and institutions within the network. This ensures adoption and facilitates communication and tool development across all disciplines. By working in resource poor and resource rich systems simultaneously, synergies in process and methodology will be gained. Production and conservation issues provide the major focus for management intervention. This interdisciplinary network will integrate our scientific understanding and provide insights into climatic and agricultural processes (Figure 7.8). This must be accompanied by a rigorous assessment of the technical possibilities that demonstrate where climate information and seasonal climate forecasting can positively influence systems performance. These technical possibilities must be evaluated for their socio-economic feasibility. This iterative process can only be achieved via a participatory research approach that involves all players.

To be successful, such a network will require a long-term financial commitment with dedicated staff working on specific issues at various research centres around the world. Equally important will be an effective network management that ensures that component research is focused on the target system and provides the types of output that can be used by other network partners as either input for further analyses or as base line data for necessary assumptions. At a minimum following major program areas need to be resourced at a range of research centres:

- Project coordination and communication
- Climate science (from climate models to agricultural models)
- Agricultural systems modelling and field scale modelling
- Socioeconomic analysis, farm/village/regional level modelling
- Institutional analysis and guidance
- Communication / Training
- Training and capacity building

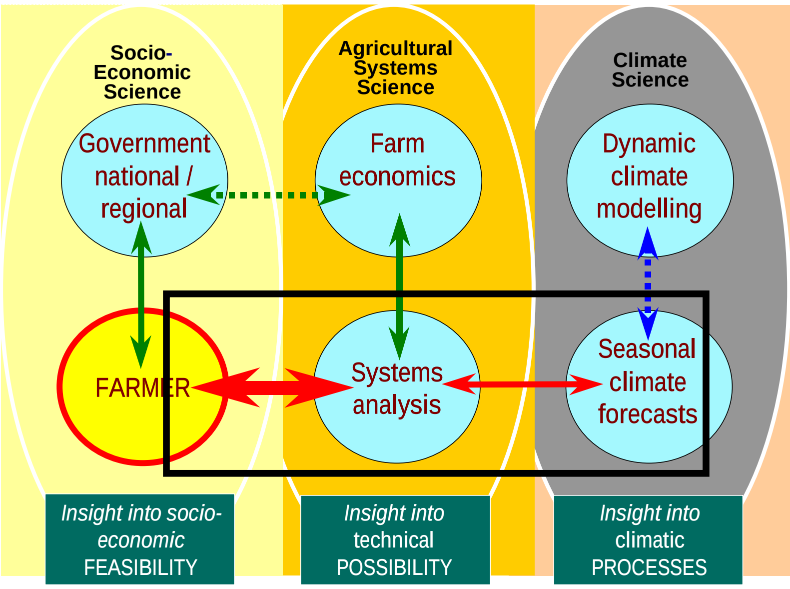

Figure 7.8 Network concept[1] showing disciplines, relationships and linkages for effective delivery of climate information for decision making. The boxed area indicates the

[1] see *Meinke, H., Baethgen, W.E., Carberry, P.S., Donatelli, M., Hammer, G.L., Selvaraju, R. and Stöckle, C.O., 2001. Increasing profits and reducing risks in crop production using participatory systems simulation approaches. Ag Systems, 70: 493-513.*

realm of the CLIMAG South Asia Demonstration Project. Operational links are indicated by the solid arrows and show connections that have proven useful in the more developed parts of the SAT (i.e. Australia, USA and South America). Dashed arrows indicate areas where operational connections that need to be developed via RES AGRICOLA.

7.10.2 The RES AGRICOLA Network

The network will be global in its outlook with an emphasis on relevant knowledge and wisdom acquisition and dissemination and a clear intention to intervene in order to achieve better outcomes. However, by using a case study approach, local relevance and appropriateness will be ensured.

The process builds largely on approaches that have proven successful in the pilot study and similar programs in Australia, USA and South America, which have demonstrated that climate information and climate forecasting can be value added via a systems analytical, participatory research approach. RES AGRICOLA will provide a means to reduce vulnerability caused by exposure to climate variability at the field, farm household and village level. Analysis of policy options, constraints and their feedbacks on on-farm management will form an important part of this research network.

7.10.2.1 Goals

The overall goal is to refine and deliver a general methodology or process for reducing vulnerability of farming systems operating under climatic risk. Seasonal climate forecast information is an integral part of this process, as is a formal agricultural systems analysis that is cognisant of the given socio-economic framework. RES AGRICOLA will work closely with decision makers in vulnerable farming systems at targeted locations to:

- Identify, evaluate and refine viable decision options that will benefit from forecasts, using a participatory research approach.
- Analyse decision options tailored to forecasts at the field, farm and village scale.
- Address information and communication needs of farmers and other decision makers.
- Adapt seasonal climate forecasts to the needs of decision makers and to the scale of decisions.
- Document existing institutional support networks and policy environments.
- Analyse options for policy intervention that will foster resilience in farming systems
- Engage and equip relevant institutions that will operationalise the process on a sustained basis.

7.10.2.2 Approach

Building on the pilot study, RES AGRICOLA will continue to work at current project locations in southern India and northern Pakistan, and expand the effort to include other locations in Asia (e.g. China, Indonesia, Sri Lanka, South America, and Australia). There are clear benefits (as well as challenges) from working across a diverse set of farming systems in multiple locations. Multiple sites provide an opportunity to leverage and evaluate the robustness of the process, and its component tools and methods. The network will be comprehensive by addressing all elements that are essential to realising the potential benefits of seasonal climate prediction: understanding of decision makers and options, skill and scope of climate prediction, communication, and institutions and policy. At the end of the expected 10-year establishment period, RES AGRICOLA will have established a highly effective, fully functional interdisciplinary network of experts that will be self-sustaining and serve as nodes for further capacity building in the future. RES AGRICOLA's approach can be described as:

- *farmer-focused.* RES AGRICOLA will engage with targeted groups of farmers to understand and analyse their production systems and their decision environments. These farmer groups will be research partners in the participatory co-learning process. Issues will be addressed at the field, farm household and village scales.

- *a case study approach.* Fostering operational use of climate prediction by a large segment of the farming community requires a 'learning-by-doing approach'. This will be achieved via comprehensive case studies, working closely with targeted groups of decision makers. This provides an ideal basis for future capacity building.

- *a quantitative systems approach.* The RES AGRICOLA team and its sponsoring institutions have substantial collective experience and documented successes in applying such approaches in Australia, USA and South America. They are world leaders in the effective use of probabilistic information for better decision making.

- *a participatory co-learning process.* Decades of international agricultural development have taught much about the importance of involving farmers in the research process. Through this process the RES AGRICOLA team will learn how to support local decision making and how to communicate skilful, probabilistic climate forecasts without distortion.

- *policy-relevant*. Government policy has a profound influence on the economic environment of decision makers. Policy may either enhance or constrain the ability of agricultural decision makers to respond appropriately to forecast climate conditions. In order to inform policy, our decision analyses will consider the implications of current and alterative policy scenarios and involve local policy agents.

- *building institutional ownership and facilitated capacity building.* Local institutions must eventually become responsible for the process to fully benefits from the case studies. RES AGRICOLA will collaborate with institutions that express interest and can support the production, dissemination and application of seasonal climate forecasts by the agricultural sectors.

The current CLIMAG South Asia team brings together experts and institutions from four countries, all with considerable expertise, commitment to the network's principles and continuing project activities climate and agricultural systems research. However, the successful establishment of RES AGRICOLA clearly requires additional areas of expertise – such as in social and economic sciences and pasture and rangeland management.

To date this initiative has received financial support from the international agencies APN, START and NOAA-OGP. In partnership with these organisations RES AGRICOLA is now seeking on-going investment to pursue the network's goals. Initially, this is likely to happen on a project by project basis. Further details can only be developed as the full scope of the project emerges.

For further information regarding RES AGRICOLA please contact Dr Holger Meinke at APSRU (holger.meinke@dpi.qld.gov.au) or Amy Freise at the START Secretariat (AFreise@agu.org).